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REGIONS
FLUORSPAR DEPOSITS OF THE USSR

Systematic investigations and surveys of the fluorspar deposits which have been carried out in recent years on the territory of the USSR have disclosed a number of extremely curious and characteristic properties of these deposits, their genesis and age relationships, the development of which has, without doubt, the greatest significance as an indicator of the direction of prospecting and, in a number of cases also, geological prospecting. These characteristics, as far as it appears at the present time, are determined dissimilarly ^{in the description of} ~~for the~~ different deposits ~~in the de-~~ ^{regions} ~~scription of them in the different districts~~ of the USSR.

The following feature of the distribution of the fluorspar deposits is extremely characteristic. In the southwest, as if in a single arc that begins in Central Asia and South Kazakhstan, are located the Takob, Khaydarkan, Aurakhmat, and Badam deposits, the largest in this part of the arc, judging by the status of our knowledge to date.

Then there are deposits of Western Siberia -- the Suyengin and Irbin. Naturally, the possibility is not excluded of locating, also, a number of other deposits in the region of Northern and Southern Kazakhstan, of which there are already indications.

Further to the northeast are the numerous fluorspar deposits of the eastern Trans-Baikal region, which lie near the area of development of the high-temperature stannic-tungstic and mesothermal polymetallic deposits.

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Still further to the northeast, fluorspar deposits are developed in the region of the Amur River (Boruchan), and on the Chukot Cape, apparently, are large, but little-studied, deposits.

The age conditions of these deposits are extremely diverse; it is characteristic that in proportion to movement from southwest to northeast, we find younger and younger deposits. Thus, the age of the large-scale Takob fluorspar deposit, which is found in the region of Central Asia (and which is especially well studied in regard to geology and tectonics), judging by the data of the IMS, *Institute of Mineral Raw Materials*, is variscite.

The same age is also possessed by the Kulikolon deposit of optical fluorspar, located in the region of the Zeravshan Mountains, and also by the Khaydarkan and Aurakhmat deposits; consequently, the age of these deposits, as well as all Central Asian and South Kazakhstan deposits, is the variscite.

In light of these data, great importance is acquired also by deposits, information concerning which is very limited. These deposits fall into that same fluorspar zone of variscite age; they have been located in recent years on the Kurtka River in the Kirgiz SSR, and also discovered by A. Amiraslanov at the source of the Kunus River to the east of the city of Frunze and elsewhere.

The deposits, situated somewhat to the north of this fluorspar-bearing line, namely the Suyengin deposit of Western Siberia, are considered to be considerably more ancient, the age of which relates to the "tel'besskiy" or Caledonian disturbances.

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The fluorspar deposits in the region of Eastern Trans-Baikalia, where their formation, judging from the data of the detailed investigation of the Institute of Mineral Raw Materials, is closely connected with Alpine folding, are still younger.

Apparently still younger in age, the Cretaceous, are the Boguchan deposit and that of the Chukot Peninsula.

Thus, on a large scale, a certain regularity in the appearance of an increase of fluorspar-bearing veins of all the later ages is contemplated in proportion to movement from west to east.

It is characteristic that the age of one of the largest deposits of fluorspar -- the ^aAnderma -- is also considered variscite.

In regard to the characteristics of mineralogical composition and paragenesis, certain characteristic features are observed, which, up to a known degree, distinguish the more ancient fluorspar deposits -- the southwestern -- from the younger -- the northeastern, which ^{fact} is ^{due} connected ^{to} with the difference in the processes of separating the fluorspar hydrothermal solutions from sulfide minerals.

The ancient, western fluorspar-bearing regions are characterized by the fact that they are usually poly-mineral regions, and the fluorspar is indissolubly combined there with granular minerals of different zones, but precisely with lead and zinc sulfides. Typical examples of such deposits are the Takob in the south, the ^aAnderma in the north and, in part, the Aurakhmat. But sometimes they are lower-temperature, typical epithermal deposits

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and are combined with cinnabar and antimony glance, as this is extremely characteristic of the Khaydarkan deposit.

In certain cases they are characterized by the fact that the fluorspar is extremely closely combined with barite; an example of such a fluorspar-barite deposit is the Badam deposit, where sulfides also exist in small quantities, particularly famatinite (Cu_3SbS_4).

Only in one case was there encountered an almost completely mono-mineral deposit of completely white, colorless, aqueous-transparent optical fluorspar -- the Kulikolon deposit, typically of an epithermal nature. But usually the presence of deposits of polymineral composition are characteristic for the fluorspar deposits of the entire western region of the USSR.

A completely different picture is obtained for the region of the eastern part of the USSR, and in the first place for the region of development of the fluorspar zone in Eastern Transbaikalia, where deposits of fluorspar have a typical mono-mineral character. They do not completely contain sulfides; the fluorspar is accompanied in them by modifications of silicic acid. At the same time, a short distance from this fluorspar belt are areas of such oxide ores as tin spar, wolframite and a number of other minerals which are close to the formations of pneumatolytic genesis.

Regarding the fluorspar-bearing deposits of the east in the USSR, there are two groups among them, in general of epithermal character, namely, the higher temperature type, Solonech, and the lower temperature type, Kalanguy, which differ from each other by the lesser or greater distance from the origin of their formation.

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All of these pertain in essence to the hydrothermal formations with the following temperatures: of formation ^{for the first mentioned deposits} ~~for the first~~ of above 300 degrees, and ~~for the second~~ of under 150 degrees, ^{for the last mentioned deposits}.

THE FAR EAST

Prof. N. S. Lavrovich

DESCRIPTION OF THE DEPOSITS OF THE FAR EAST

Two deposits of fluorspar were known before the Revolution: the Boguchan on the Amur and outcroppings of separate veins of fluorspar in the region of the Vantsin River and the Yevstafiy Bay on the ~~Japanese~~ ^{or Japan} Sea. But these deposits were not completely studied and explored, and their industrial value was not seen clearly up to that time.

Fluorspar is considerably more widely distributed in this region than was known earlier; this is verified by the discovery in 1931--1932 of new veins on the Chukot Peninsula, which have, apparently, industrial value.

Up to the present time in the Far Eastern Territory, three fluorspar regions are known: the Chukot, Primorskiy and Priamurskiy. In spite of the great distance separating them, they all belong to the Upper Cretaceous Period, and, perhaps, also to later times, and are connected, apparently, with intrusions of granite and effusions of liparites.

There is no doubt that further geological studies of the territory will expand considerably the area of distribution of fluorspar.

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THE CHUKOT PENINSULA

The expedition of 1931-1932 established the following places where fluorspar occurs.

1. Fluorspar in the form of fine crystals was encountered by the geologist, N. S. Donskiy, at several points along the rocky sea-shore between Cape Serdtse Kamen' and the village of Chevnitsa, and, in one case, on the Chevnitsa River.

2. Accumulations of the finest fluorspar crystals were found in the Uzlen Mountains of nephelinic syenite; however, not one of these points containing fine accumulations has any practical importance.

3. In the northern part of Krësta Bay, on the Piypkun River, five kilometers from its mouth, is located a quartz-fluorspar vein. The latter cuts through clay slates collected in the anticlinal fold of the northwest trend, at a sharp angle, and the northwest trend also has an abrupt, almost vertical, slope. The vein is revealed in the cliff of the left bank of the river, cropping out on the slope at 40 meters and is detected to the north for a distance of 1 kilometer. The thickness of the ore at the outcropping reaches nearly 4 meters, although the vein in the upper part is split up into several branches.

Outcroppings of fluorspar are not found in the cliff of the right bank, and it is possible that the ore veins to the south either are thinned out or are displaced by disjunctive breakings along the bed of the river (on an east-west line).

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and fluorspar, judging by the experiment of the Trans-Baikalia deposits, in the described mineralogical composition of the vein, the method of damp jigging is used successfully. The problem of transportation is completely solved by the Great North Sea Route.

PRIMORSKIY DISTRICT

A considerable area on the shore of the Japanese Sea between Yevstafiya Bay and the Avvakumov River and to the west of the sea, approximately 30 kilometers (Skalistaya Canyon), shows indications of the presence of fluorspar formation in the form of small veins, seams and accumulations.

The occurrence of fluorspar is established for the following points.

1. Between Pfusun and Yevstafiya bays, near the mouth of the Teniv'ya River, is an outcropping formation of metamorphized shist, cut through by quartz porphyries and overlapping them by tuffs. The shists extend in a northwest direction -- 300-330 degrees / 40 degrees -- northeast and is cut through by a series of fine veins of fluorspar of from 1 to 8 centimeters thick. For a distance of nearly one kilometer the occurrence of 46 seams is established. Fluorspar is encountered in the form of green, often transparent crystals, octahedral or cubical in form. The trend of the seams varies. One and five-tenths kilometers from the Teniv'ya River, for a distance of 1-1.3 kilometers, in the midst of the metamorphized shist, cut through by veins of the andesite type, veins of fluorspar are encountered.

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2. On the Mramor Cape, where the marble and granite rock come together, occurs a vein-like mass of calamine, with spots of lead glance, among which fluorite in the form of small veins is found.

3. Not far from the mouth of the Vantsin River, to the south of the village of Milogradovo, approximately 6 kilometers from it, granites appear on the shore of the sea, intersected by porphyries and sometimes by fine veins of fluorspar.

4. On the right bank of the Vantsin River, near the village of Milogradovo, a vein of fluorspar appears among the granites of a thickness up to 0.1 meter and with a trend northeast 29 degrees /60 degrees northwest.

5. The presence of more than 20 veins and streaks, often of completely pure fluorspar, up to 0.15 meter thick, is established at 6-7 kilometers to the east north-east from the preceding point, among porphyries and porphyritic, tufaceous breccia. The length of the fluorspar zone is established as approximately 0.25 kilometer.

6. Quartz veins, containing lead-zinc ore, occur 37 kilometers from the Ol'ga station, in the Semenovskiy Valley, among porphyries and tuffs. The presence of fine veins of fluorspar in the vicinity is established.

7. The presence of druses of small cubes of fluorspar is observed among the porphyry in the vicinity of the lead-zinc deposit in the rocky valley along the Avvakumovka River.

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Thus, outcroppings of fluorspar occupy a considerable area; although they do not possess a favorable nature in relation to thickness, it is necessary to note that the region has been studied extremely superficially and to draw a negative conclusion regarding the possibility of finding commercial deposits would be premature.

The region unconditionally deserves geological-prospecting operations at an angle not only to the occurrence of veins of pure fluorspar but also of fluorspar diffused in the rock, if only in an amount of 30-40 per cent and higher. Modern engineering flotation rigging used at the Amdermink deposit (Karsk Sea coast) showed the complete profitableness of such ore in regard to content.

AMUR TERRITORY

The Boguchan deposit has been known since 1894, and was described for the first time by L. F. Batsevich. During the years 1915-1916, prospecting work was carried out at the deposit by the Geological Committee, in the person of the geologist, V. P. Rengarten. In 1925, the deposit was explored by workers of the "Rare Elements" Trust.

The deposit is coordinated to a small volcanic mound, which is located 6.5 kilometers from the shore of the Amur River and 15 kilometers to the west of the entrance of the latter into the Malokhingan Canyon. The vicinity of Boguchan is swamped and the volcanic mound itself is surrounded as if by a ring of water.

The populated points nearby the deposit are the Pashkovo settlement 15.6 kilometers to the south-east and the Sagibovo

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settlement 10-11 kilometers to the south-west. From the Kundur station of the Amur Railway, it is 30 kilometers to the deposit. In view of the absence of well-organized roads, Boguchan is hard to reach, particularly for the transportation of freight.

From the geological point of view, the youngest rocks in the region of the deposit are those deposited by the Amur River, alternately strata of fine sands and sandy clays with fragments of wood.

The Boguchan volcanic mound itself is built up of strata of stratified rock, with a predominance of tufaceous material. The latter forms fine seams of varying thickness among the sandy and clayey material, which contains large pebbles. The clayey and sandy material is encountered rarely; seams of clayey tuffs and tufaceous sands, comparatively thick, predominate. Petrographic studies carried out by A. Gerasimov showed that the rock consists of liparite fragments with a basic mass of micro-granite and with phenocrysts of quartz and minute grains of orthoclase. Here and there sections are composed continuously of spherulites. All the fragments are linked by a small quantity of yellowish, isotropic opal. On the basis of a microscopic study, the rock is determined as a liparite, tuff-conglomerate with opaline cement.

Among the described sedimentations are found plant remains, which A. N. Krishtofovich identified as Asplenium Dicksonianum Heer; Ginkgo adiantoides Heer; Coniferae sp.; Platanus cf. affinis Lesq.

On the basis of these determinations, the geologist Rengarten

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refers the stratum of rocks to the upper Cretaceous age.

In the northern part of the deposit, the upper Cretaceous sedimentation is cut through by a dike of liparite and vitrophyre.

In the upper Cretaceous epoch, according to Rengarten, possibly also even in the Paleocene, on the plain adjoining Malyy -Khingay; the formation of a thick covering of alluvial sedimentation took place, simultaneously with the sedimentation of volcanic ashes. In the part of the uplands lying next to the plain, in addition to the discharges of volcanic ashes, an outpouring of liparites occurred, which yielded, chiefly, the material for the rubble. The volcanic activity occurred also in some parts of the plain.

Following the outpouring of liparites, the entire seam of rocks in the vicinity of these outpourings were subjected to the action of pneumatolytic and hydrothermal processes, with which the formation of fluorspar also is connected.

The outpouring of liparites was preceded by disjunctive disturbances, which are expressed in the deposit in the formation of fissures, for the most part almost of a meridional trend, with a vertical drop or at an angle of 83-87 degrees to the west. These fissures are detected for a considerable distance and veins of fluorspar conform to them. The fracturing of latitudinal trends plays a smaller role, possessing the character of faults and causing breaks and dislocations of ore bodies.

Ore crevices are determined by prospecting for a distance of nearly 380 meters and are an entire complex of contiguous veins

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with a trend north-east 6 degrees--south-west 231 degrees. Through all the deposits passes the so-called main vein, from 0.7 up to 1-1.5 meters in thickness, accompanied from the east and west by small veins and streaks, which are from several centimeters up to 0.3-0.4 meters in thickness. The thickness of the veins is extremely variable; frequently they narrow down, branch out, thin out or develop into breccia, where the fluorspar acts as a cement. The material composition of the ore bodies is as follows (in order of predominance): fluorspar, chalcedony, quartzite and antimony glance.

The purest varieties of fluorspar are encountered in the northern part of the deposit, where it possesses a grayish-green color and solid-crystal structure in completely octahedral cleavage. The violet variety is observed almost exclusively only in thin veins and incrustations.

In the greater part of the veins barren rocks are admixed with the fluorspar. Modifications of silicic acid are coordinated to the suspended side of the veins.

The antimony glance is distributed unevenly in the area of the vein, with separated accumulations in the form of small seams and veins of slight thickness up to 5-6 centimeters, but usually considerably less thick. The mineralized rock is not only fluorspar but also secondary rocks, principally of the suspended side. In places, according to chemical composition, the ore is characterized by its high quality, and contains (according to S. Konstantov): S 9.70 per cent; Fe 0.45 per cent; traces of As; and traces of Au. The barren rock comprises 65.8 per cent.

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The order of mineral-formation is as follows: fluorspar, antimony glance, chalcedony, quartzite and opal. The genesis of the deposit is hydrothermal in connection with the intrusion of liparites.

The exploitation of fluorspar unconditionally requires beneficiations from an admixture of barren rocks or by the method of crushing and manual sorting, or flotation.

An approximate yield of fluorspar, suitable for industry (chiefly metallurgy), consists of an amount in the vein of 50-60 per cent in a content of CaF_2 of 80-85 per cent.

Individual samples showed the following content: central part of the vein: CaF_2 99.40 per cent; Fe_2O_3 traces; SiO_2 0.60 per cent; suspended side: CaF_2 88.50 per cent; Fe_2O_3 0.60 per cent; SiO_2 10.90 per cent.

The deposit has not been investigated definitely, and the resources according to the classification comprise group S1 chiefly, with a numerical expression of 20-25 thousand (up to the level of the Amur River). The reserves of antimony glance were not calculated.

EASTERN SIBERIA

N. S. Lavrovich

DESCRIPTION OF THE VEINS OF EASTERN TRANS-BAIKALIA

Fluorspar has been known and developed in Eastern Trans-Baikalia for over one hundred years. The names of present-day

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settlements -- Gasimuro-zavodskiy, Aleksandro-zavodskiy, Nerchinsko-zavodskiy -- indicate some development of mining here (in the 18th and 19th centuries), which has lost all significance, at the present time, in the form it had when these plants were in existence.

Now there remain only traces of the plants in the form of slag heaps, which indicate their work with iron and poly-metallic ores.

In particular, the great demand for fluorspar by the Kutomarskiy, Ducharskiy (1834) and Nerchinskiy plants called into being the Solonechnoye deposit; the Aleksandrovskiy plant, the Pura and Algachinskiy deposits and Man'kovskiy. In all of these deposits traces of the exploitational work are preserved in the form of forest over-growth in the open pits or piles of fluorspar-covered bryophyta.

The next stage in the extraction of fluorspar at the deposits of Eastern Trans-Baikalia occurred during the period of the imperialistic war of 1914-1918, when the Abagaytuyskiy and Sedlovskiy deposits were brought into operation.

A vigorous and systematic development, both in regard to extraction and also in regard to scientific-research work, of the deposits of Eastern Trans-Baikalia was produced in connection with the First Five-year Plan for the industrialization of the USSR, and, by 1936, at the active mines, over three tens of thousands of tons of commercial fluorspar has been extracted.

The merit of the fluorspar deposits of Eastern Trans-Baikalia

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is that their ore bodies are almost completely mono-mineral. This permits the satisfying, using only manual sorting, of the requirement of metallurgy of ferrous metals and certain kinds of chemical and silicate industries. At the same time, the impossibility of obtaining fluorspar for the production of cryolite with a content of CaF_2 not less than 95 per cent, in large quantities without mechanical sorting, the remoteness of Eastern Trans-Baikalia from the centers of demand (over 6000 kilometers), and the remoteness of the deposits from the railway (from 47 up to 270 kilometers) are great negative factors, placing certain limits on the expansion of extraction.

The recently discovered, huge fluorspar deposits of Takob in Tadzhikistan and Vaygach (Andermin) to the north, with the completion of construction on their concentration plants, will be insuperable competitors for Eastern Trans-Baikalia in view of their more advantageous location relative to the centers of demand and future high quality capacity for production of goods (for the chemical industry).

Regions and genetical types of deposits. The fluorspar deposits of Eastern Trans-Baikalia can be divided into the following groups.

The Turga group, situated in the basin of the Turga River, is represented by the Kalanguy, Taming, Devyataya Pyatnitsa, Zmeyev, Otsoluy, Duturul, Kovrizhka and Byrychka deposits.

The Priargun'skiy group, which includes the deposits situated on the left tributary of the Argun' River, namely:

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Solonech, Puri, Man'kovsk, Urulyunguy, Khara-khazagorsk, Urtuy, Chirsk, Abagaytuy, Bugutursk and others.

The Onon group is in the basin of the Onon River, with the Kuranzhinsk and Dul'durgin deposits.

In addition to the enumerated groups there are the Sedlovsk and Dagoysk deposits.

The coordination of a deposit to some type of rock or to the formation of a definite age is absent. The Jurassic or post-Jurassic age of a deposit affords the right of asserting the possibility of its occurrence within the limits of Eastern Trans-Baikalia in any original rocks of any age. Within recent times the presence of fluorspar veins has been established in the metamorphic sericite-quartzitic shists and crystalline limestones, relating to the Paleozoic era, in the Paleozoic and Mesozoic granites, in the sands, clay slates and conglomerates of the lower, middle and upper-Jurassic Age and so forth.

Basically, it seems possible to distinguish two types of deposits: the high-temperature (of which the Solonech deposit is a typical example) and the low-temperature (the Kalanguy deposit type). A variety, comparatively often encountered, is the type intermediate between the two named types, and which serves as a transition from one type to the other, approaching now the high- now the low-temperature deposits in each individual case.

The high-temperature type of vein substance mostly is coordinated to the Jurassic and post-Jurassic granites and granodiorites.

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Fluorspar is characterized by an intensity of color and compact-crystal structure. Violet and green colors predominate, with gradual transitions from one to the other; lesser fluorspar is dull, colorless or greyish-white color. All of the fine fragments of fluorspar, as though they were not colored, are translucent.

Large fragments of fluorite break up, upon being struck, into octahedral fragments of from millimeters up to several tens of centimeters in diameter. Upon fracturing, quartz or chalcedony in the form of fine veinlets (sometimes ten parts of a millimeter) are present usually in fluorspar; they sometimes envelop the fluorspar on all sides on the fracturing of the fragments. Quartz and chalcedony in the form of several generations are invariable accessory minerals of deposits of the high-temperature type; they form a thick network of veins and veinlets that cut through the fluorspar in various directions. They are concentrated on the suspended side with thick veins. Frequently, radially radiating bristle-shaped accumulations of quartz crystals are present around the fragments or crystals of fluorite, chiefly of a green color. Silicic acid, directly connected with the fluorspar, is found in quantities rarely exceeding 1 per cent. A large portion of the structure of the ore body is occupied by quartzitic-fluorspar breccia, usually coordinated to the casing.

The high-temperature type of deposit is created, apparently, not only by a hydrothermal process but also by a pneumatolytic process in its final stage. The temperature of the formation of the deposit fluctuates within the limits of 300 to 400 degrees. This temperature did not promote the formation of typical hydro-

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thermal minerals, and the mineralogical composition of the vein substance is identified as quartzitic-fluorspar. The main mass of silicic acid is crystallized at the beginning of the formation of the deposit. Simultaneously, and for the most part as a consequence of this, the crystallization of the fluorite from the cooled solutions took place, whereupon there was formed, primarily, fluorspar of violet, green and grayish-white colors. The dark colors more frequently are coordinated to the casing, particularly the horizontal. The formation of a modification of silicic acid and fluorite took place in several successive generations; as a result, the color of the fluorspar, maintaining the referred to sequence of formation, becomes all the less intensive. Secondary rocks usually are changed by the processes of silicification, chlorination and sericitization.

In form, the veins of the high-temperature deposits are complex, with numerous branches and of variable thickness.

The low-temperature type of deposit is removed from the source of its formation (as is shown in the chapter "Genesis of Deposits" from granites and granodiorites) and is found principally in sedimentary-metamorphic strata of the Jurassic Age. In contrast to the high-temperature type, low-temperature fluorspar has a less intensive coloring of light-yellow, weakly rose-colored and light-violet colors. Frequently, colorless varieties are encountered. The basic mass of fluorite has a ribbon-like symmetrical structure, with elongated-columnar crystals, situated parallel to one another and perpendicular to the casing. In the thickest portions of the ore body, the central part is filled with

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spherical or elliptic radially-radiating concretions of columnar crystals with concentric accretions. Usually, in the center of such concretions a core of fragments of barren rock or fluorspar itself is present. Between the individual concentrations are found thin layers (from a fraction of a millimeter up to 1-2-3 millimeters), which consist of kaolin and fluorspar, cemented by silicic acid (but not always). The thickness of the concentrations varies; it is less at the periphery than at the center of the concretion. The size of the diameter of a concretion varies from 0.1 up to 0.5 meters, seldom more. Vein quartz is absent; the silicic acid that is present is amorphous; it impregnates the fluorspar with separate bands or sections, particularly intensive near the under side, and creates the silification of the rock enclosing this side. The suspended side of the enclosing rock is considerably kaolinized and a certain amount of kaolin is present in the vein substance.

In the cavities of the vein, fine clayey material of greasy texture is often present, stained by oxides of iron to a reddish-brown color. The oxides of iron generally are present in the ore body in considerable quantities and in places color the fluorspar to a brown color.

The temperature of formation of the deposit is from 150 degrees and lower.

Thus, the low temperature releases almost entirely the ore body from the accompanying minerals, and the amorphous modifications of silicic acid are coordinated principally near

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the under side. Only in the deep horizontal veins are encountered small accumulations of fine pyrite crystals. The process of kaolinization begins to play an important role.

In mineralogical composition, the vein substance is monomineral, and the deposit bears the kaolin type.

The vein substances of the low-temperature deposits have a complex structure of relatively constant width along the course and in the dip (within the range of depths disclosed by prospecting).

The third variety of deposit, being intermediate between the types described in regard to the structure of the fluorspar, possesses a more complex mineralogical composition. The fluorspar possesses a different color, as in the high-temperature deposits also, but is less intensive and always with a grayish shading. In the structure of the fluorspar, transitions are observed from solid crystal to columnar structure; frequently the veins have a symmetrical ribbon-like structure. Very seldom are incompletely developed spherical concretions encountered. The ribbon-like symmetrical color of the fluorspar is especially clearly expressed, which, in the high-temperature deposits, is only partially observed. The order of formation of the colors is similar to the first type of deposit. Silicic acid is represented principally by chalcedony with a zonal structure and, in lesser degree, by quartz, both being located chiefly in the casing of the vein. Both in the fluorspar and also in the silicic acid modifications, several generations of formation is established. In the central parts of the vein, barite, nacrite and kaolin are present, the first in the form of well-formed

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crystals. Excellent pseudomorphoses of an argillo-kaolin fluorspar aggregate are observed often in the barite. These pseudomorphoses on the surfaces are covered by the "Korochka" of the columnar fluorspar.

Thus, this form of deposit, according to mineralogical composition, is referred to the quartzite-barite-fluorspar type, and is poly-mineral. In form, the ore bodies do not have, generally, sharp variations in thickness, but frequently they are beaded, with a large number of fine branches. The temperature of formation of the deposit fluctuates within the range of from 150 degrees to 300 degrees.

The intermediate form of deposit, like the low-temperature deposit, is hydrothermal.

The question of the even or uneven distribution of silicic acid modifications in the vein substances along the dip is not only of theoretical but also of considerable practical interest. In case of an increase of the content of silicic acid in deposits with a depth as great as the cavity of cleaning work, it is possible to expect a decline in the quality of the products during the use only of manual sorting. In this regard, this question has the most serious significance for the low-temperature deposits, where the silicic acid is overwhelmingly amorphous and manually practically inseparable from fluorspar.

The Kalanguy deposit, being a typical representative of the low-temperature deposits, according to the data of the general assaying of mining (1931), showed an average content of SiO_2 of

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12.78 per cent and CaF_2 of 82.15 per cent. The re-calculation of the content of SiO_2 in the individual horizons that was carried out obliges us to come to the conclusion that the diffusion of silicic acid in the deposit is more complex.

Below, data is cited on the content of SiO_2 in fluorspar according to the horizon, starting with the upper (Table 1, see page 14).

From the data cited, it is seen that the gradual increase of SiO_2 content with depth is observed. From a comparison of the figures brought out above and the vertical height between the separate horizons, it is possible to calculate, if only approximately, the increase in the content of silicic acid with the depth for one running meter, assuming the increase in the content of SiO_2 according to arithmetical progression. This increase on the average is equal to 0.27 per cent SiO_2 per 1 running meter. Performing

Table 1

No. in order		Content in %	
		SiO_2	CaF_2
1	Gallery No. 2.....	8.69	85.50
2	Drift Pit No. 1.....	9.47	85.88
3	Gallery No. 1.....	14.50	79.54
4	Gallery No. 3.....	19.91	76.62

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such a calculation for the Solonech deposit showed the increase in content of silicic acid in the form of veinlets of quartz to be 0.45 per cent per 1 running meter (for parts of the vein consisting principally of fluorspar). The figures brought out on the increase of the content of SiO_2 with a depth of one running meter, of course, are approximate, but oblige us to come to the conclusion that the content of the modifications of silicic acid in the deposits of Eastern Trans-Baikal is unconditionally increased with the depth. Especially rapid increase can be expected in deposits of the high-temperature type.

TURGA GROUP OF DEPOSITS

The deposits of the above-named group are located in the Borzinskiy Rayon of the Eastern Siberian Kray and are centered in the upper part of the Turgan River basin. The intersection of the meridian 116 degrees 45 minutes and north latitude 51 degrees 02 minutes, to the east of Pulkovo, is located approximately in the central part of the region of the deposit. The closest railway station is Khadabulak, on the Trans-Baikal Railway (57 kilometers south-west of the Kalanguy mine), over which fluorspar is shipped to the consumers from all of the active mines of the Turga group.

The Rayon is situated in the mountains of the Gazimuro-Onon Range, which is a southern spur of the Yablony Range. The greatest absolute geodetic altitudes -- to the north of the region, also, they reach 1200 -- are 1270 meters. In the west and south, generally, there occurs a lower relief, with altitudes from 740 to 950 meters. Negative points of the relief descend, in places,

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to 620 meters (valley of the Turga River and its middle course). In the general north-east direction of the Gasimuro-Onon Range, separate ridges of mounds do not always maintain this trend, owing to the fact that there was in its time a strong erosion, which created numerous depressions of a different direction.

The morphology of the individual mounds is divided into two basic types, depending on the nature of the rocks composing the mounds. Mesozoic formations, determined relatively easily by the eroded rocks, give the relief a smooth outline. But the crystalline rocks (especially of a young intrusion) create rocky summits and abrupt forms of positive relief. The negative relief is represented by river valleys and depressions, which played a significant role in the transformation of the locality. In the southern part of the region, a development of the relief is frequently encountered in the form of open amphitheatres, into which flow small ravines, in a fan-shaped formation (Taminga, Otsoiuy, Bypykcha and others). The length of the depressions themselves varies and fluctuates within the range of from one-two up to several tens of kilometers.

The Turga River valley, stretching in a north-east direction within the area described, is very narrow near its source, but in its middle course suddenly broadens out and attains a width of more than 10 kilometers, forming the so-called natural landmark of Tsunguruk-Tala. The natural landmark is an open plain with well-preserved or dried-up lakes and salt marshes. The Turga River and its tributaries are mountainous in character and during the rainy period are transformed into stormy streams,

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difficult to negotiate. In dry years, not only the tributaries, but even the Turga River is capable of drying up for a considerable distance, and during the winter freezes to the bottom. The decline of the river valleys fluctuates within the range of 0.015 near the sources to 0.0025 in their lower courses.

The character of the river waters is subject to great variations, independently of precipitation and temperature. In the summer months, at the end of July and in August, a rise in the level of the rivers is observed on account of the maximum thawing of perpetual frost at that time. The thawing of perpetual frost is reflected also in the mountain development, where the lower levels are usually water-collecting points.

The discharge of water in the rivers, for 1932, a year of abnormal precipitation (the month of September), was 2-2.5 cubic meters per second for the Turga and 0.020-0.025 cubic meters per second for the Kalanguy. The presence of perpetual frost almost everywhere creates an unusual ground water circulation. The latter is divided into: waters flowing over the frost and waters flowing under the frost, in alluvial formations; waters which circulate in the fracturing in original rocks.

The least reliable waters are those flowing over the frost, for which the perpetual frost serves as a water-resistant channel; these are encountered, for example, in the valley of the Kalanguy River, at a depth of 3-4 meters. The waters under the ice circulate among the alluvial formations of the river valleys, below the lower limits of perpetual frost, which are found at a depth of

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11-25 meters (Kalanguy River valley). The waters that circulate in the fracturing of original rocks, as shown by prospecting at the Kalanguy deposit, are the most reliable, and the inflow from the drill holes amounts to 3.6 liters per second. The geological structure of the region plays a significant role here, apparently, consisting in an alternation of steep and comparatively sloping synclines and anticlines. The first are often built up by sandstones, which promote the accumulation of waters, the more so that the sandstones are interstratified with slates, which can serve as a water-resistant level.

The climate of the region described, according to the data of the meteorological station at Borzys, is continental, with a large temperature range according to the time of the year and in the course of a day. The lowest average monthly temperature is observed in January (-27.2 degrees, -29.5 degrees), the highest in June +20.3 degrees, +28.4 degrees). Average monthly temperatures below zero occur during the course of 7 months in the year, from October to April. The average yearly temperature is below zero, which is characteristic of a region lying in the belt of perpetual frost.

The greatest quantity of precipitation falls in July and August, the least in January and February.

The northern and eastern parts of the area (the mountainous parts) are densely forested, principally deciduous. To the southwest from this area, a forest-steppe belt passes through, where the birch plays the chief role, and still further on in the same direction the forest-steppe becomes a steppe.

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Geologically, the region of the deposits is built up by sedimentary rocks of the Paleozoic, Jurassic and Quaternary Ages, by crystalline -- intrusive and effusive, vein and metamorphic rocks. In degree of diffusion, the sedimentary and crystalline rocks play an almost identical role. It does not seem possible to analyze the Paleozoic formations more in detail in regard to age and, generally, the determination of them as Paleozoic is conditional in view of the absence in them of remains of fauna and flora.

According to its petrographic composition, it is possible to divide a stratum into several stratigraphic levels.

The crystalline rocks are separated, according to age, into ancient (pre-Mesozoic) and young (post-Jurassic). According to petrographic composition, a group of granitoids and basalts predominate. Veinstones are encountered in all areas and are represented by acid and basic, "askhistovyy" and "diaskhistovyy" rocks.

Quaternary sedimentations are coordinated to the hollows and river valleys, and are divided into ancient-bench and recent-bench sedimentations.

Sedimentary rock.¹ (¹ The petrographic study was conducted by Ye. A. Petrov.). The Paleozoic stratum is revealed chiefly in the south-west part of the area; single outcroppings (crystalline limestones) are encountered in the northern part of the area. In petrographic composition, the stratum consists of amphibolic shales,

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chloritic and biotitic shales, limestones, hornstones, jasper-like rocks and quartzites.

The repeated, intensive dislocations of rocks which is taking place strongly complicate the question concerning their stratigraphic inter-relationships, but in a detailed study of the sections, the sequence of deposit is depicted in the following manner. The lower level is ferrous cherts overlapping with shales, sometimes alternating with biotitic shales. Here and there, chloritic shales pass over into plicated and more rarely into silicified shales. The shistous level is covered by strata of quartzites and jasper-like rocks. The upper level is amphibolites and amphibolic shales. Among the latter are encountered small strips of limestones, sandstones, silicified shales and jasper-like rocks. Normal amphibolites are a rock of dark-green color, sheared, with a formation of striated structure. Nodules attain a size of 0.5 centimeters. The principal rock-forming minerals are amphibole and plagioclase, rarely quartz. Usually they have a large occurrence of secondary minerals -- epidote, biotite and sericite. Of the accessory minerals -- titanite, apatite, ore mineral. Hornblende comprises nearly 70 per cent of all the rock.

The genesis of the rock which has been described in unclear inasmuch as a microscopic study did not establish any indications of the matrix. On the one hand, in structural characteristics, they are close to diorites, up to a certain degree, small intrusions of which break through the amphibolites in this region. On the other hand, apparently, the amphibolites

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gradually pass over into amphibolic gneiss, which is encountered in the form of small layers and which, in structure, approaches paragneiss. The occurrence of seams of limestones also are forced to yield to the primarily sedimentary genesis of the amphibolites; Den'gin and Sheynman [72] refer the amphibolites and the amphibolic shales to the orth-series.

Together with the amphibolites, pure hornblendites are encountered. They are disclosed by separate outcroppings, and it is almost impossible to establish their inter-relationships with the amphibolites. If it is possible to mistake them for rocks clearly connected with the amphibolites, the question of their genesis depends on the solution of the genesis of the amphibolites themselves.

The crystalline limestones, referred to the Upper Paleozoic Period, are present in individual outcroppings to the south of the Turga crystalline range and to the north of the village of Turga on the Kovrizhka mound.

The Mesozoic stratum, which predominates in the area of occurrence over the Paleozoic, is represented by the Lower, Middle and Upper Jurassic. The Lower Jurassic is represented by a basalt [Basal] conglomerate with remains of fauna of the Upper Liassic. The basalt [Basal] conglomerate is traced by a narrow strip almost solely at the northern boundary of the mesozoic sedimentation and is well-expressed at places where it is deposited in the ancient granite (Taming Range). The lower part of the basalt [Basal] conglomerate represents, in structural form and mineralogical

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composition, a very hard separable layer of granites which lay under it, and only the frequent presence of rolled granite pebbles, with a size of 0.5-1.5 centimeters in diameter, and sometimes even more, produces an outward difference from the granites.

The cement consists of a quartz-feldspar mass. Both the feldspar -- microcline -- and also the individual, sharply undulating, fading nodules of quartz which are often enclosed in it are strongly disintegrated and are divided by the fracturing. The feldspar and the larger nodules of quartz are welded together by the broken, small aggregate of the quartz-sericite mass.

Large-grained, grayish-yellow arkosic sandstones overlap this stratum, the former being overlapped in turn again by the conglomerates. The conglomerates are light-gray, extremely large-grained rock of fragmental structure. The basic mass of rock is built up of angular, weakly-rolled fragments of transparent quartz, of white, sometimes slightly pinkish, feldspar, of thin leaves of black mica and black, well-rolled pebbles of slate. Such a character of the basic mass recalls the granite breccia, but among these little-rolled fragments of average size (up to 8 millimeters) is contained nodules of that same black, dense slate of up to 6 centimeters in size, white aplite-like granites up to 1-2 centimeters in diameter and light-gray, dense siliceous shales.

The quantitative proportions of all the components are expressed in the following figures: quartz--28.0 percent, plagioclase--8.8 per cent, orthoclase and microcline--23.4 per cent, fragmental rock--26.8 per cent, cement--13.6 per cent, and the remaining components--6.0 per cent.

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The general thickness of the basalt [basal] conglomerates is from 40 to 80 meters.

The slates, which are deposited on the basalt [basal] conglomerates and which also refer to the Lower Jurassic, have a wide-scale diffusion in the north and east of the region. In external form, they are represented by dense, dark, almost black, rocks with greenish or gray-blue shadings. Microscopically, it is sometimes possible to detect in them the isolated fragments of those same shales, sometimes darker, granites and separate minerals (quartz, feldspar, mica, pyrite and so forth). The most abundant area of fragmental granites in the slates is observed near the stratum of the basalt [basal] conglomerate. Here and there is observed a well-expressed, thin primary cleavage. Brown ferrous oxides in considerable quantities are usually present on the surfaces of the stratum. The slates, in large part, have a well-expressed foliated structure, the layers of which under impact are divided into very thin scales. Frequently the foliated structure is not absent at all almost and the rock assumes the form of an argillaceous rock (according to Pilipenko).

According to petrographic composition, in the slates are distinguished a phyllite type and biotite slates.

The phyllite type of slates, or the fine sericite-clay slates, in external form differ from the usual clay slates and are black dense rocks, in which only on the surfaces of the foliated structure scales of sericite glitter, giving the rock a silky luster. Under the microscope, to a rather considerable degree,

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is noticed the crystallizing off of clayey material; together with the amorphous clayey particles is observed a large quantity of scales of sericite, less large leaves of biotite, nodules of quartz not more than 0.01 millimeters in size, and winding aggregates of feldspar, which are formed from the argillaceous substance. The dark color is dependent on the presence of a considerable quantity of carbonaceous substance, which under the influence of metamorphism frequently passes over into graphite. Accumulations of carbonaceous substance and graphite are coordinated to the surfaces of the foliated structure in the form of elongated seams or strips. Through a number of successive transitions a sharp change is observed in the composition of the phyllites. First of all the content of biotite is increased, here and there chloritized, which forms brown scales. Together with the biotite, muscovite is sometimes developed in the form of elongated, large thin leaves, together with accumulations of quartz nodules, which form aggregates of elongated forms.

Of the secondary minerals in both types of slates there are encountered: tourmaline, titanite, zircon, and pyrite. Rarely, small seams of arkose and graywacke sandstones are encountered, chiefly in the upper parts of the stratum.

The stratum described above accordingly is covered with alternate sandstones and slates, which are referred by I. V. Khudyayev [71] to the upper parts of the "batskiy" stratum. Here and there (the Antiya and Sektuy rivers) this stratum is represented substantially by sandstones. The rocks of the "batskiy" stratum are diffused more widely in the area of the

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Turga group of deposits, and all of the exploitable deposits of fluorspar are included in this formation. The stratum is differentiated into slates and sandstones, in a whole series of transitions from slates through sandy slates to sandstones and from sandstones through argillaceous sandstone to slates.

The interstratification of the sandstones with the slates so close and dense that to divide the stratum is successful only in a large scale geological survey. The sandstones are represented by arkose and graywacke varieties. The mineralogical composition of the arkose sandstones is as follows: quartz, plagioclase, orthoclase, muscovite, sericite, biotite, calcite and cement. Apatite, as an admixture, is encountered from time to time, as is tourmaline, ore mineral, zircon and sphene. The cement most frequently of all is represented by a brownish, amorphous clayey mass, which contains the most minute inclusions of those same minerals, with quartz and feldspar predominating. The cement is confusedly granular, sandy-clayey, basal, that is, was formed simultaneously of the nodules of the rock itself.

The fine-grained arkoses are a phase change of the average-grained and transitions to slates.

The graywacke sandstones are divided into two groups, according to color: the black and dark-gray, and the light-gray, almost yellow, sandstones. Such a difference in color in an almost identical mineralogical composition is explained, apparently, by fluctuations in the quantitative relationships of the content of the components and the amount of clayey material in the substance.

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The color of the arkoses is often darker than the color of the graywackes, owing to the presence of a clayey substance in the cement of the first.

The structure of the graywacke most often of all is uniformly granular; the size of the fragments, on the average, is not more than 1 millimeter. Sometimes these rocks pass over into fine-pebble conglomerates. In lithologic composition, the graywackes between the strata and essentially of the sandstone stratum are different. The graywackes of the sandstone stratum are characterized by a somewhat more variegated composition. In them are encountered fine pebbles of clayey, sandy-clayey, siliceous slates, quartzite, diabasic porphyrites, diabases, aplites, pegmatites and felsites. A variety is observed also in the cement. In the sandstone stratum, the cement is clayey-sandstone with a predominance of fragmental material; often this cement, generally, is absent. But in the graywackes between the strata the cement is chiefly clayey. For comparison, figures are cited below of the mineralogical determination of sandstones between the strata and essentially of the sandstone stratum (Table 2).

Besides the fragments of rocks in the sandstones there are present acute-angled nodules of quartz, plagioclase, orthoclase and calcite. As secondary minerals are detected: apatite, tourmaline, pyroxene, epidote and cericite.

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Table 2

Composition of the Graywackes	Graywackes of the Sandstone Stratum in %	Graywackes between the strata in %
Quartz.....	11.3	17.7
Orthoclase.....	4.3	2.0
Fragments of sedimentary rocks.	45.5	35.6
Fragments of igneous rocks.....	13.5	—
Plagioclase.....	11.4	9.5
Matrix.....	13.7	35.0

The mineralogical composition of arkoses and graywackes is represented in Figure 1.

Sandy-clayey slates of the between the strata form a transitional level, on the one hand, to sandstones, and on the other hand, to clay slates. Macroscopically, they are black, dense rocks, in which the fragmentary material can not be seen with the naked eye. Schistosity is not observed in them; the foliated structure is coarse (platy cleavage).

Under a microscope it is seen that the rock consists of clayey material, which is made up of approximately 80 per cent rock, fragmental nodules of quartz and feldspar, scales of sericite, kaolinite, biotite, ore mineral, and zircon. The size of the fragments is 0.05-0.1 millimeter; their form is irregularly angular. Secondary changes of the rock are expressed, on the one hand, in the

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formation of numerous fine scales of sericite in the clay material, and on the other in the sericitization and pelitization of the feldspar.

% Content of Other Minerals

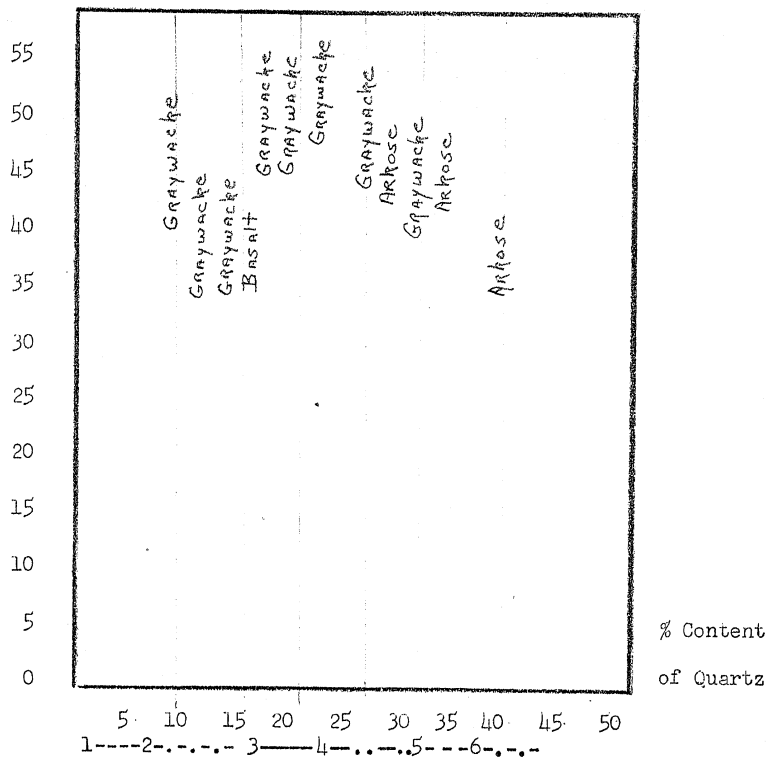


Fig. 1. Curves of Mineral Contents in Sandstones

[Errata: Page 21, Fig. 1. Legends omitted: 1 -- Fragments of sedimentary rocks, 2 -- Matrix, 3 -- Quartz, 4 -- Orthoclase, 5 -- Plagioclase, 6 -- Fragments of igneous rocks.]

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Clay slates are the most diffused rock. This black, bulky rock, with slight hardness, is close-grained and coarsely-laminated. Seam-like streaks of quartzitic-calcareous sandstone are encountered sometimes in it. Under a microscope it is seen that the slates are built up of brown, clayey, amorphous substance, in which almost imperceptible scales of kaolinite are translucent. Inclusions of fine, 0.03-0.01 millimeter, acute-angled fragments of quartz, feldspar and biotite are observed. With an increase in amount and size of these nodules, the slates pass over already into a sandy-clay variety.

Conglomerates, which are referred by I. Ye. Khudyayev to the Upper Jurassic Period, and for the upper parts of the stratum the possibility of the presence of Cretaceous age is even considered by him, occur in the central part of the area and to the east of it.

In macroscopic structure, the conglomerates may be divided into two groups: large-pebble conglomerates, approaching detritus, and small-pebble conglomerates, transitional to graywackes.

The large-pebble conglomerates represent dark-gray, massive rocks, which consist of pebbles of black, dense clay slates, well-rolled and flat, with sizes of 1-10 centimeters in diameter, of pebbles of light-gray siliceous slates up to 1-5 centimeters in diameter, and pebbles of fine-grained sandstones. These fragments are cemented in certain places by a black, dense substance of clay slate, in others by fine-grained sandstone. Often, impressions of flora, which are described by I. Ye. Khudyayev and others in detail,

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are encountered. Small-pebble conglomerates are formed of detritus of clay and siliceous slates, quartz, feldspar, with a size of not more than 5 millimeters in diameter, and cemented by sandy-clay material.

Under a microscope the conglomerates have the following composition: quartz, plagioclase, orthoclase, microcline, biotite, pebbles of clay and sandy-clay slates, quartzites and granites. The secondary minerals are sericite, calcite, chlorite and epidote.

The cementing substance of the conglomerates most of all consists of extremely fine fragments of clay slates, which sometimes passes over into a compact clayey, non-fragmental mass, always with scales of kaolinite, sericite and quartz. More rarely, this clay material passes over into granular sandstone cement. The cement occupies an area of diffusion in the conglomerate of less than the fragmentary material, filling in the spaces between the nodules and possessing a confused, granular structure. The quantitative mineralogical composition of the conglomerate is as follows: quartz--20.6 per cent, feldspar--11.2 per cent, fragments of granites--2.9 per cent, fragments of slates--18.2 per cent, cement--40.0 per cent, the remainder--7.1 per cent. The calculation was carried out from the medium-granular part of the conglomerate without large pebbles.

Near the granite blocks of the conglomerate, the contact reactions strongly vary, as a consequence of which the rock possesses a lighter color and a vaguely expressed fragmental structure. A considerable number of quartz veinlets and granite

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veinlets is present. Individual parts are strongly silicified.

In conclusion it should be noted, relative to all Jurassic sedimentary rocks, that they are the product, unconditionally, of a shallow basin or riparian phase.

In petrographic composition, the sandstones and slates entirely match the granites and are crumbling and not far removed granite material. Even the composition of the plagioclases, as shown by a study of the crystalline rock of the region, near the sandstones and granites is completely similar.

For the shallowness of the sedimentation also speaks the presence of a considerable quantity of ferrous oxides in the clay shales in the strata, the excellent preservation of the flora in the sandstones, etc.

Quaternary formations (Q) are concentrated principally in deep ravines and river valleys, where they have a considerable thickness. Their composition, evidently, varies little in separate parts of the region, and therefore it will be sufficient to bring forward a profile of the Quaternary sedimentations of the Kalanguy River valley. Basically, the valley is filled by gray clays with a content of a large amount of admixtures that are large in mechanical composition, from large broken stone to sand, occasionally of sedimentation of so much broken stone that the rock has the character of stonework, which is connected by a cement which is solidified clay. Among these formations there was not encountered clearly expressed sedimentations in those or other characteristics, with the exception of the seams of black clay which are encountered.

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The greatest amount of large mechanical admixtures -- broken stone, pebbles, gravel and grit -- are encountered down to a depth of 8-10 meters. All of the material of the coarse admixtures has an extremely low degree of rolled-ness, and in petrographic composition is built up of clay slates, gray and dark-gray arkose sandstone and granite. The character of the sedimentation in all dimensions is expressed unevenly and with a thinning out.

Crystalline rocks. Crystalline, intrusive rocks are broadly developed in all the areas described and are represented by three significant mountain ranges: Taming -- of Paleozoic age, Turgin and Suktuy -- of post-Jurassic age.

The granite of the Taming Range, which is located in the north-east of the region (towards which, transgressively, leans the Jurassic stratum), has a cataclastic structure and is represented by a medium-granular, finely-micaceous variety of grayish-yellow color; it is compact and in rare cases, in parallel arrangement, the mica passes over into schistose. In the almost latitudinal schistosity being observed, with a dip to the north and south, the granite is fractured in a cleavage in the following fracturings: south-west 110 degrees $\angle$ 75 degrees west; north-east 85 degrees $\angle$ 5 degrees south; north-east 35 degrees; south-east 108 degrees $\angle$ 30 degrees north.

Under the microscope, the granite, basically, consists of light-gray, frequently of twinned feldspar, less of quartz and biotite. The feldspars are represented by microcline with a characteristically lattice structure and plagioclase with a well-

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expressed poly-synthetic twinning according to the Carlsbad and albite laws of coalescence. Of the secondary minerals, epidote and chlorite in association with biotite are encountered.

In almost all of the rock-forming minerals is noted traces of partial fragmentation; in the microcline this is revealed in the diminution of the clearness of the lattice structure, in the quartz is observed a sharply expressed, undulating dying out, in the fracturing of all the nodules and in the convexity of the twinning plagioclase. Possessing a subhedral-granular structure, the granite, owing to the large-scale deposit of microcline, sometimes passes over into a porphyritic.

The post-Jurassic mountains, namely the Turga in the central part of the described region and the Suktuy to the south, cut through the Jurassic stratum and metamorphize it at places of contact.

The Suktuy Range is heterogeneous and contains orthoclase granite-pegmatites and granite-porphyries, adamellites and granodioritic biotite-hornblendes.

The first group -- the granite pegmatites and granite-porphyries -- are not widely diffused; outcroppings of them are encountered usually on contact with the Jurassic stratum. They form, apparently, a marginal phase.

The biotite granite-pegmatites are a medium-granular, light-gray, almost white, rock, in which white feldspar can be seen with the naked eye, smoke-colored, coarse nodules of quartz and black

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leaflets of biotite. Under the microscope, the following are found in the composition of granite-pegmatites: orthoclase, microcline, quartz, and biotite. Of the accessory minerals there is ore mineral. The quantitative relationship of the minerals is expressed in the following figures: quartz--23.8 per cent, orthoclase and microcline--72.5 per cent, and biotite--3.7 per cent.

The structure of the rock is micropegmatitic (granophyritic); a sharp xenomorphism is observed of all the components and close, mutual intergrowths of the quartz and feldspar, and also the sinuous form of the biotite. All this speaks for the simultaneous crystallization of the components of the rock of the minerals.

The alkaline granite-porphyrries have a porphyritic structure with a fine-grained basic mass. The phenocrysts are formed by a pale rose-colored feldspar 1 centimeter and less in size. The structure is compact.

Under the microscope, the rock consists of phenocrysts and a basic mass. The phenocrysts are represented by orthoclase, plagioclase and quartz (in a lesser amount).

In the basic mass is quartz, orthoclase, plagioclase, microcline, biotite, and hornblende. The accessories are pyrite, zircon, apatite, and fluorite.

Adamellites in the structure are divided into three groups: adamellite-aplites, adamellite-porphyrries and strictly adamellites. This variety is observed both macroscopically and microscopically. All three groups are encountered within the limits of the central

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part of the range, the first in the north of the range, nearer to the marginal zone, the second in the center of the range, and in the intervals between them are the normal adamellites. The composition of these rocks is almost identical: quartz, plagioclase, microcline, biotite and muscovite. In the dark-colored adamellite-aplites there is very little. The quantitative relationship of the minerals in these three groups of adamellites is approximately identical: quartz from 28.6 to 41.7 per cent, orthoclase and microcline from 20.2 to 37.3 per cent, plagioclase from 26.2 to 30.0 per cent, biotite from 2.7 to 7.9 per cent, and the remainder 5.2 per cent.

The proportion of feldspars to quartz fluctuates, but the quartz is never lower than 25 per cent.

Granodiorites are encountered in the periphery of the range, especially at its western extremity. They are gray, medium-grained and compact, and contain much biotite and quartz. Porphyry-like, coarse-grained varieties are encountered, where the porphyritic deposits belong to the plagioclase.

Under the microscope, the component parts of the granodiorite are plagioclase, quartz, orthoclase, microcline, hornblende, and biotite.

The accessories are titanite, tourmaline, apatite, ore mineral. The secondary minerals are sericite and chlorite. The structure of the rock is normal sub-hedral-granular.

Granodiorites of the Turga Range belong to the microcline-plagioclase type. In external form, they are coarse-grained,

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light-gray rocks, which contain dark-gray streaks of granodiorite with biotite. Plagioclase (albite-oligoclase), quartz, microcline, and biotite enter into the composition of the granodiorites, and their accessories are apatite and ore mineral. The secondary changes are insignificant and lead to the appearance of rare scales of sericite, turbid aggregates of kaolin and epidote. Plagioclase predominates in amount. The structure of the rock is granitic; the order of deposit of the minerals is regular.

Intrusions of post-Jurassic granites, granodiorites, etc., produced the following modifications in the Jurassic sedimentary strata. Clay slates at contact are generally colored, purified and converted into nodular, chistolitic, graphitic, micaceous, biotitic-garnet slates or sericitic hornstones. Similarly to the slates, the sandstones and conglomerates also undergo certain changes, which result in the de-crystallization of the clayey cement into aggregates of fine grains of quartz, biotite, and sericite. The de-crystallization of the clayey cement is usually encountered somewhat beyond the point of contact. The sandstones near the point of contact are strongly silicified, sericitized and chloritized.

The zone around the point of contact rarely reaches a thickness of 100 meters.

To distinguish all of the described varieties of intrusions on a map does not seem possible, inasmuch as they are indistinguishable, in large part, under field conditions. But for the young intrusions, it is certain that the granodiorites occupy the

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peripheral part of the ranges. Orthoclase granite is encountered both in the center and also on the periphery of the ranges. Apparently, the assimilation of the secondary rock took place. A streaky differentiation took place in the ancient range, inasmuch as it is difficult to trace any regularity in the diffusion of the various types of granites and the granodiorites in them.

With regard to petrography, there is almost nothing to distinguish the ancient from the young intrusions. It is necessary to note one characteristic feature of the ancient granites, which results in the formation of sericite and calcite at the expense of plagioclase, kaolin at the expense of orthoclase and microcline, chlorite from biotite and amphibole, rarely of epidote in the plagioclase and amphibole. The displacement of the primary minerals by the secondary occurred so strongly that frequently it is very difficult to find relics of the primary minerals. These changes are connected, apparently, with the action of hydrothermal solutions in the post-volcanic phase of the ancient and young granites. It is certain that these two phases changed the ancient granitoids to a greater degree than the young.

The rock-forming minerals of the ancient and young granites are the same, and their quantitative proportions in similar rocks are rather close (Fig. 2).

The division of the granites into two formations, produced by Muzylev -- the onon is ultra-acid and the argun is more basis -- hardly can be verified by the example of the ranges of the described region according to the following considerations. The

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ranges have a too heterogeneous composition and in them, together with extremely acid granites, are encountered the more basic, up to the granodiorites inclusively.

And, despite this, the young granites are accompanied principally by gray lamprophyric veins in the insignificant development of the aplite-pegmatitic granites; by this is explained the fact that the region is barren of pneumatolytic deposits.

The presence of veinlets of rocks of ancient intrusions in the region is not determined, which, possibly, is explained by their covering of the Jurassic sedimentary strata.

Effusive rocks, represented by the basalts, are found in an insignificant area in the south-west corner of the region. Macroscopically, they are diverse, together with vitreous varieties granular varieties are encountered. The color fluctuates from dark-violet to green. The structure is compact, sometimes schistous. Under the microscope it is seen that in the brown mass are buried elongated plates of plagioclase, often with simple twins. In the basic mass, in the brown limonitized glass, are buried irregular yellow nodules of epidote, calcite and ore mineral, biotite and chlorite. The structure of the rock is "afit": "leysty" of plagioclase are cemented by all the remaining components.

Veinstones are wide-spread in the region, especially among the Jurassic deposits. They can be divided into acid, medium and basic. The first, in insignificant quantity, is represented by aplites, pegmatites, quartzitic porphyries, granites with varieties

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granite-porphyries and hornblende granites, granodiorites and granodiorite-porphyries; the medium and the basic are represented by diorites, diorite-porphyries, porphyrites with the varieties hornblende, hornblende-plagioclase, pyroxene-hornblende, pyroxene, also spessarite, gabbro and diabase.

All of the veinstones occur in the form of dikes or veins; they intersect the sedimentary rocks either transversely to the trend (more often north-east 5-15 degrees) /50-80 degrees north-east, or at an acute angle to it. In addition, they achieve a breaking up of the fracture which runs along the trend of rocks (at the contact of strata of different structure). It is not possible to determine their age inter-relationships in relation to the trend, since no sequence of the formation of the fractures of that or any direction exists. In the latter case, the rocks often are of insignificant thickness. But in general, the thickness fluctuates from several centimeters up to 10 meters, rarely more. The angle of incline fluctuates from 15-20 degrees to vertical. In quantity, the medium and basic rocks predominate over the acid.

The veinstones are characterized by great diversity; among them are present transitions from the ultra-acid, the type of the aplites and pegmatites, to the basic types of the gabbro and diabases. The transitions from one type of rock to the other (from granites to granodiorites etc.) bear witness to how completely the differentiation of the magmatic fusion took place. The mineralogical composition of all the veinstones and the granites

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produced is very close. The indicated rocks do not always form separate substances; frequently, within the limits of one and the same dike are observed transitions of plagioclase porphyrites to hornblendes or dark-colored granites (which appear under the microscope with the granodiorites or the diorites) into the leucocratic granites. Besides the difference in mineralogical composition of the rocks, structural differences also are observed. Frequently, the peripheral phase of the dioritic dike has a porphyritic structure. But sometimes the porphyritic rocks are formed of a vein altogether. Among the porphyritic rocks are encountered varieties that are different in structure from the basic mass. Together with the well de-crystallized basic mass of porphyritic rocks, approximating them to the intrusive rocks, are encountered rocks with a fine-grained, weakly de-crystallized basic mass, peculiar to the effusives. All this attests to the fact that the conditions of stratification of the veinstones were, by far, not similar. Certain ones were crystallized under conditions no different than the conditions of solidification of the intrusive granites, others under the conditions of hypabyssals, and the third ones under still colder circumstances, similar to the solidification of the effusive porphyrites.

The main and most diffused component in veinstones is plagioclase; its composition varies, with a content of anorthite of from 8 to 45 per cent. The more basic were not encountered, in spite of the presence nearby of basic rocks. Regarding the origin of the veinstones, they are all connected with the post-Jurassic intrusion and are products of its differentiation. The vein phase

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of the ancient granites is concealed, apparently, as was shown, by the Mesozoic strata.

The tectonics of the region of the Turga deposits. Not indulging in polemics with M. M. Tetyayev on the questions of the tectonics of Eastern Trans-Baikal, which is composed, in his opinion, from tectonic contacts in connection with the covering structure of Paleozoic and Jurassic stratification and which are in essence absolutely incongruous, the tectonics of the Turga region is as follows.

The Paleozoic and Jurassic sedimentary strata is built up in the region in a huge syncline with a north-east trend and with a dipping of the axis to the north-east. In the south-east of the region, the syncline passes over to an anticline of the same trend.

The northern wall of the syncline is built up by a Jurassic strata (J₁ -- J₂), which, transgressively, leans on the Paleozoic crystalline range (Taming Range); the southern wall is formed by that same Jurassic strata and its Paleozoic foundation. Analyzing the conditions of stratification for each strata in particular, two basic trends can be established: north-west for the Paleozoic and prevailing north-east for the Jurassic. Characteristic is the change of the north-east trend to the north-west for the Jurassic strata in places where it leans on the Paleozoic and the particular change here of the north-west trend to the north-east for the Paleozoic (the watershed between the Turga and Antiz rivers). This phenomenon is explained by the fact that already being in the presence of a folded Paleozoic north-west trend, the folded

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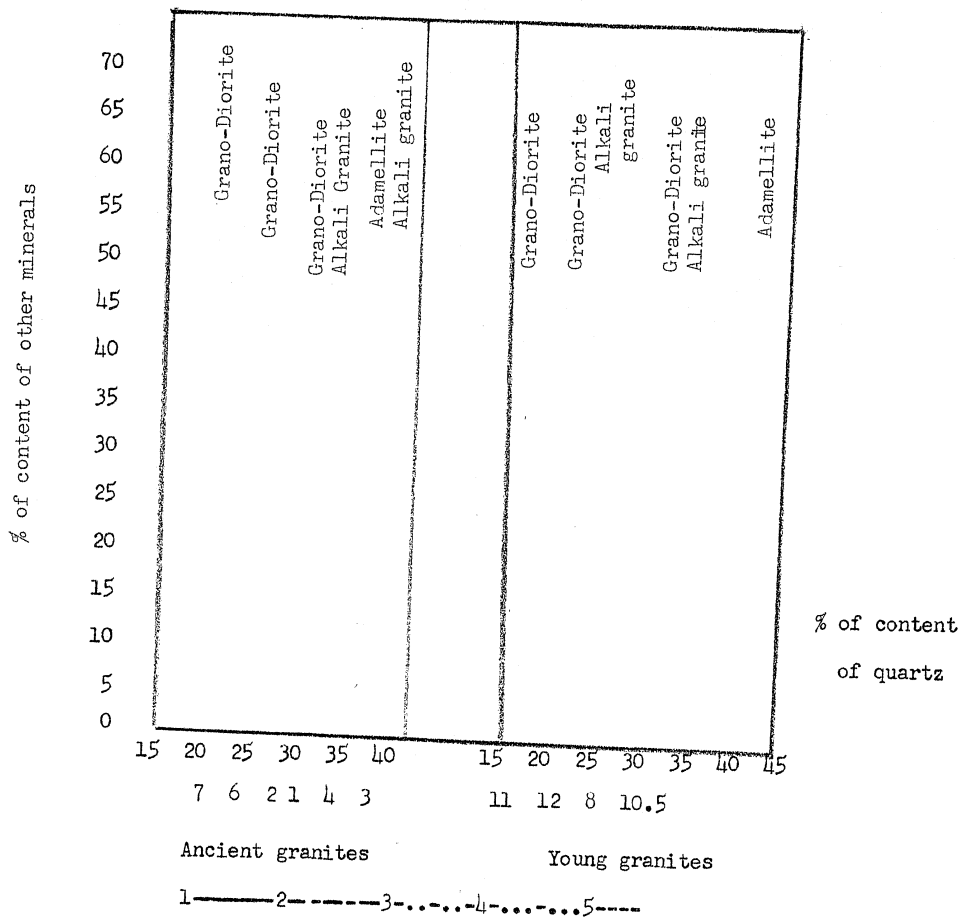
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Fig. 2. Curves of Mineralogical Composition of
Ancient and Young Granites.

[Errata: Page 27, Fig. 2. Legends omitted: 1 -- Quartz,
2 -- Biotite, 3 -- Plagioclase, 4 -- Orthoclase, 5 -- Hornblende.]

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system was reflected in the next dislocation. Actually, in the north and north-east of the Turga region, where Paleozoic formations are almost absent, Jurassic sedimentations have a north-east trend, normal for Eastern Trans-Baikalia, consequently being a thrust from the north-west (and not from the south-east, according to M. M. Tetyayev). Since the Paleozoic with a north-west trend comes out on the daytime surface only, the Mesozoic also assumes this trend. Hence, the final conclusion can be only that, having been shaped into an inflexible folded system, the Paleozoic influenced the Jurassic, and, secondarily, assuming the orogenic processes also collapsing together with the Jurassic, here and there it caused the latter partially to assume a trend to the north-west, as the Paleozoic itself here and there changed the trend toward the latitudinal and even the north-eastern. The concentration of large disjunctive dislocations (faults, overthrusts and fractures of the thrust) precisely in the place where the Jurassic formations bend from the north-east trend to north-west, that is, in the place of greatest tangential pressure and greatest reaction of the Paleozoic formations, serves as evidence of a similar phenomenon. All of the fluorspar deposits are concentrated in this, if it is possible to express it thus, structural aggregate. The described syncline and south-east anticline (its north-east wall) are complicated by the folds of the second and third order, whereas the range of the latter are insignificant and scarcely reach several tens, rarely hundreds, of meters. The dip of the walls occurs on both sides and reaches from 30 to 65-75 and even 80 degrees. Often, folds (of the second and third order) are present, of an isoclinic nature, principally with the northern

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dip (especially to the north of the region), which leads to a false idea regarding the thickness of the strata (Freyval'd, Pilipenko and others).

If between the Paleozoic and the Jurassic is observed an unconformable variation, then accordingly the formations occurring between the lower and Middle Jurassic also unconformably occur with the Upper Jurassic conglomerates. This phenomenon is shaded strongly owing to the block character of the folding of the conglomerates.

It should be noted, by the way, that the geologist Den'gin [72] characterized the strata of conglomerates as an interstratification of the latter with the sandstones and the slates. Actually, the strata of conglomerates (J₃) is preserved in the synclines of the Middle Jurassic deposits, represented by the sandstones and slates, and the insignificant, anticlinal bends (folds of the second and third order) of basement rock (J₂) projecting from under the conglomerates, in a cursory examination of the region, create the impression of an inter-stratification. The latter led to the error of the geologist Den'gin, who calculated, owing to this, a width for the Jurassic strata of the described region of several kilometers.

In conclusion, the geological past of the region comes to the following. The sedimentary strata, pertaining unconditionally to the Paleozoic, was subjected to crumpling (it is possible, during the variscite time), together with which a powerful volcanic action developed, yielding the ancient granites (Taming Range), under the influence of which the sedimentary strata of the

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Paleozoic also was metamorphized.

The Paleozoic strata was built up into a complex system of folds, often isoclinic, with a general trend north-west 300-330 degrees. In addition, apparently, they were fractured also by disjunctive transgressions, the existence of which is completely certain; for them speak the frequently encountered crushed rocks and the sharply contrasting trends.

The mountains that had been created then were subjected to denudation, and on the eroded surface of the Paleozoic was deposited the Lower and Middle Jurassic. The lithological composition of this strata, composed of sandstones and slates, indicates that it was deposited in depressions, near big continental mountain ranges or in shallow basins. The shoaling of the basin occurred exceptionally rapidly, and the schistous strata of the Lower Jurassic rapidly passes over into the sandstone-schistous strata of the Middle Jurassic.

At the end of the Middle Jurassic, the first phase of the "kimmeriy" folding took place, giving to the strata a general north-east trend for 50-60 degrees and impinging on the Paleozoic. In connection with this there took place the shoaling of the water basin and the intensive accumulation of the strata of conglomerates of the Upper Jurassic. The second phase of the "kimmeriy" folding at the end of the Jurassic and the beginning of the Cretaceous, of approximately that same direction, was accompanied by a huge intrusion of granites (principally of granodiorites) with a vast complex of veinstones. The metamorphism of all the Jurassic

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stratum and the formation of the deposits of fluorspar are connected with this intrusion. The "kimmerly" folding was accompanied by disjunctive transgressions, which were expressed in the formation of horsts and grabens. In the latter were preserved the Jurassic formations of the ensuing erosion (the Jurassic deposits among the Taming granites in the south of the region).

In a study of the basalt [basal] conglomerate within the limits even of Eastern Trans-Baikalia only, the variation of age is observed to the side of the transition from the more ancient to the younger (from the Lower to the Middle Jurassic) in the direction from west to east. This phenomenon obliges us to come to a conclusion regarding the transgression of the Jurassic basin in Trans-Baikal from west to east.

The width of the entire Jurassic strata in the conditions of the tectonics cited is approximately 500-600 meters.

The commercial deposits of fluorspar of the Turga group are concentrated around the crystalline range of that name, genetically connected with it and located in relation to the range in the form of an open ring. Fluorspar is found not only on the north-east and east side. The trends of the deposits maintain directions rather exactly in conformity with the contours of the Turga Range.

The absence of a fluorspar deposit to the north-east and east of the intrusion is explained by the fact that the Turga Range, as well as a whole series of others (Konduy and others), is not a body which would have broken sharply along the periphery

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or had sloping sides identical in all directions. Geological observations and prospecting indicated that the north-eastern part of the range is precipitous and sharply broken, but in the direction to the south-west has a sloping dip or incline. Thus, the projection of the north-eastern part of the range to the horizontal surface is insignificant in comparison with the south-western; consequently, the latter is also more productive in the formation of emanations and subsequent processes. The difference in the fluorspar deposits of the south-west and south parts of the region in comparison with the north-east is completely explained by this, since all other conditions are identical.

The Kalanguy deposit¹. (¹ The description of the deposit was done by the author together with I. V. Luchitskiy.) The Kalanguy Mine, which is working the deposit, has been in existence since 1926 and is located 57 kilometers to the north-east of the Khadabulak station of the Molotov Railway. The deposit is connected with the station by a broad and level road, along which there is intensive motor traffic transporting the fluorspar from the mine to Khadabulak. The road passes along the left slope of the valley of the Turga River, then crosses it and goes over the vast plain, which M. Yu. Sheynman [72] compares with depressions of the Gobi type. The Khadabulak station is also located on this plain.

The deposit is located near large villages; it is 7 kilometers to the south-west of the village of Turga and 11 kilometers to the south-east of the village of Davgokych.

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History of the study of the deposit. The beginning of the geological-prospecting work at the Kalanguy deposit goes back to 1928. Literature on the geology of the deposit can be found among the archival materials of the Union-Fluorspar Trust and in the archives of the All-Union Institute of Mineral Raw Material (Moscow). There are relatively few published works containing reports of the geological structure of the deposit and its region.

The first indications on the geology of the deposit and a brief description of the mine, with a calculation of the reserves of fluorspar, was given by V. N. Kuznetsov in 1928-1929 [85]. N. A. Smol'yaninov visited the mine at approximately that same time. The works of the engineer Artem'yev pertain to the year 1930.

In all of these works, the geology of the deposit and its mineralogy are illuminated very scantily. The manuscript account of the engineer Artem'yev contains a very concise and brief geological characterization of the deposit, with a hint on the presence of post-mineral tectonics in the deposit.

In the work of Professor N. N. Pavlov, the character of the flora encountered at the Kalanguy deposit and determined by Professor Zaleskiy is brought out. The latter hypothetically characterizes the plant remains as typical of Permian flora. Pavlov indicates that the strata of sedimentary rocks of the Permian Age, which compose the deposit, are stretched out almost in a latitudinal direction and has a monoclinial dip to the south. In origin, the deposit is pneumatolytic.

Virtually the first, most complete and detailed study of

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the mineralogy of the deposit was carried out by Professor P. P. Pilipenko [90], which indicates the absence of minerals which are characteristic of pneumatolytic deposits, and which indicates clearly expressed processes of metasomatism, on the basis of which the deposit is considered to be hydrothermal, of the epithermal and partially of the mesothermal type. In the work of Pilipenko there is also a description of the geo-morphology of the deposit, a petrographic description of the rocks of the deposit and a very brief account of the tectonics. Agreeing with the geologist Pavlov in regard to the fact that the strata of sedimentary rocks of the deposit has a general and, moreover, a monoclinial dip to the south, Pilipenko notes that the deposit is coordinated to the fault-dislocation fracture ("to the inclined fault").

From 1931 to 1934, a systematic study of the deposit and the prospecting of it was undertaken by the Far Eastern Expedition of the All-Union Institute of Mineral Raw Material, under the direction of the mining engineer N. S. Lavrovich.

In 1931, in the region of the deposit, a geological survey on the scale of 1: 10,000 was produced by Yu. I. Freyval'd.

In the account of Freyval'd [94] are the petrographic characteristic of the rocks and a brief description of the fluor-spar deposit. The author considers that the deposit is coordinated to the fault-dislocation fracture, which developed in the strata of sedimentary rocks; it has a monoclinial dip to the north and is the northern wall of a large anticlinal folding. Freyval'd refers the deposit to the hydrothermal.

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The works of the mining engineers N. S. Lavrovich and I. T. Tarasovoy also pertain to the years 1931-1935, in which are noted and considerably supplemented and worked over all the existing materials on the geology of the deposit.

Geomorphology of the deposit and its region. The region in which the deposit is located is characterized by the development of strongly smoothed out and even forms of "melkosopochnik" [small volcanic mounds]. The individual bald mountains are grouped in more or less vast, elevated ranges, bounded by large valleys and separated by deep ravines of different sizes.

The present-day rivers, with small breadth of the deeply serrated and meandering river-bed, have broad valleys with level bottoms and sloping sides of 5-10 degrees, rarely up to 15 degrees. Thus, the width of the valley of the Turga River is 1-1.5 kilometers, whereas the width of the river-bed is from 2 to 10-12 meters. In the valley of the Turga River, along its right bank, is a clearly expressed low bench of a terrace above the river 6 meters high, which can be detected also along the Kalanguy River, where it is considerably more weakly expressed. The sharply sloping sides and the disproportion of the width of the water profile of the rivers with the width of their valleys permit the assumption that in an earlier geological period, the moisture content of the climate was considerably higher. This assumption finds confirmation also in the fact that in cross sections of "delyuvial" hyy shleyf" more large fragmental material is located, as a rule, in the lower part; this much can not always explain the origin of

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the great steepness of the slopes. Nevertheless, it is necessary to note that the width of the valley is the action of a great many factors. Undoubtedly, considerable influence on the nature of the valley, on the disproportion of its width with the profile of the water current and on the formation of typical valleys above the river channel was exerted by that circumstance that the development of the denudation processes took place under conditions of perpetual frost. The prevalence of lateral erosion on the depth is a characteristic just for these conditions.

The presence here of processes of denudation, typical of regions of perpetual frost, is confirmed also by the fact that in the region adjoining the deposit the occurrence of swamping on the slopes of the mountains, mounds of swelling and the occurrence of ground waters are widely developed.

The deposit itself is located on the left bank of the Kalanguy River, on a low, meridionally elevated ridge, which is a spur of one of the lofty ranges situated to the north of the mine, between the Shiviya and Kalanguy rivers. The highest point of the deposit is nearly 1000 meters above sea level and 147.6 meters above the Kalanguy River. On the south, the ridge is bounded by the valley of the Kalanguy River, on the east by the Turga River. The ridge begins in the south, near the valley of the Turga River, and toward the north, gradually rising, passes over into the described upper range and dissects the strata of sedimentary rocks transversely to the trend.

The present-day morphology of the ridge on which the deposit

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is situated is determined by processes of denudation, the petrographic composition of the rocks which take place under conditions of perpetual frost, are characterized by intensive development of physical, expressly frost, disintegration. The physical disintegration, penetrating the rock to a depth of over 10 meters, leads to the extension of fracturing in the rocks and to the formation of acute-angled rubble and platy fragments of rock, which abundantly cover the slopes.

The crushed rocks, further, are subjected to the action of descending waters, which move the fragments of rock downhill and into the fractures in the rocks. P. P. Pilipenko indicates that the material moved into the fractures in this manner advanced up to a depth of nearly 30 meters (galleries No. 1 and 3, drift pit No. 1).

The processes of denudation, producing a general leveling of the ridge, at the same time prepare more durable rocks in relation to these processes and lead to the disintegration of the ridge in the part which has different relative heights. The most durable rocks at the time of erosion are the sandstones, porphyrites and breccia, owing to which the elevated points of the deposit are occupied by these varieties.

The influence of the petrographic composition of the rocks is told also in the small details; thus, in the alternating strata of sandstones and clay slates, the sandstones form the more projecting layers in the relief, but the clay slates are located between them in small beds.

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With the structure of the deposit is connected also the relative dislocation of the transverse ledges of the ridge on both sides of the meridional fault zone. This is especially clearly disclosed in the ledges, which are formed by the sandstones of the so-called marking level. It is probable that the small depression in the central part of the deposit is explained by the faulting along the thick zone of crushed rocks.

The following rocks form the geological structure of the area of the deposit:

A. Sedimentary: (a) sandstones, (b) clay slates, (c) rocks of "delyuvial'nyy shleyf".

B. Vein: (a) porphyrites, (b) spessarites, (c) granite-porphyrines, (d) aplites, and (e) quartz.

C. Of tectonic origin: breccias.

A. Sedimentary rocks. Sandstones. The sandstones are light-gray, more rarely yellowish-gray, coarsely-schistous, granular rocks, and their color depends on the mineralogical composition. In erosion, the surface of the sandstones is covered with a fine gray or yellowish-gray covering, the development of which occurs more intensively on acute corners of fragments. They have a platy structure; in the finer-grained varieties the structure is more finely plated. The structure is dependent on schistosity and fracturing. In the sandstones sometimes, there is observed also a schistosity which depended on a change of material; now and then it is extinguished by complex environmental changes, which are observed in the individual layers.

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Environmental changes of the sandstones are included in the transition from large-grained to fine-grained varieties, often at a small distance. These changes are detected in all directions. Thus, inside individual layers is observed the lenticular interstratification of coarse material with finer material. The size of the grain of the sandstones is extremely diverse; all varieties of them are encountered, beginning with the psephites and ending with the fine-grained psammites.

According to the size of the grain, the sandstones of the marking level are divided into the coarse-grained psammites, with a grain of 1-2 millimeters, medium-grained -- 0.25-1 millimeter -- and the fine-grained -- 0.01-0.25 millimeter.

All varieties possess a similar petrographic composition and pertain to the "polimiktovyy" sandstone type of graywacke. They consist of angular, very seldom weakly rolled, fragments, principally of black and gray clay slates and quartz. Fragments of fluorspar are constantly present, chiefly of plagioclase, more rarely of microcline and orthoclase. Sporadically, the fragments get into siliceous and effusive rocks. Biotite, apatite, hematite and zircon are found in insignificant quantity.

The cement is argillaceous, of a basalt [basal] type. In the coarse-grained varieties the quantity of cement is very insignificant; in the small-grained varieties the quantity of argillaceous substance sharply increases in comparison with the quantity of fragments. The small-grained varieties are connected by gradual transitions (by means of an increase of the quantity of

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cement and decrease of the quantity and size of the grain) with typical pelitic rocks.

Secondary changes in the sandstones lead to the phenomenon of dynamo-morphism.

Besides, in the feldspars and fragments of argillaceous rocks, in a very fine network of fracturings, small accumulations of kaolin develop. Accumulations of kaolin are developed in large quantity in the rocks, and in very strong changes they are converted into a mass of porous kaolin.

The sandstones of the so-called marking level stand out sharply among the rest by reason of their pinkish-gray color, the size of the grain and thick-plated structure, which approaches the block structure of the most coarse-grained varieties. During erosion a brown crust (up to 0.5 meters) is formed on the surface of the sandstones, enriched by ferric hydroxides.

According to the size of the grain, sandstones of this type are referred chiefly to the psephites (the size of the grain on the average is up to 2 millimeters, sometimes reaches 0.5-1 centimeter and a maximum of 2 centimeters).

Under the microscope it is seen that, of the sandstones described above, they differ only in the presence of a large quantity of ferric hydroxides, having been obtained, probably, in the disintegration of the dark-colored minerals. But the petrographic composition of them does not differ from those described above. The presence of ferric oxides in the rock more

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or less constantly and uniformly does not depend on the degree of removal of the fluorspar vein.

Among the sandstones of the marking level also are observed complex environmental changes, connected with the transition from the larger-grain varieties to the smaller-grained. Sometimes within a layer, small seams (2-3 centimeters X 15-20 centimeters) of clay slates are present.

The clay slates, in the majority of cases, are fine-grained, compact, black or dark-gray with bluish shades of color. The structure is finely-plated and is dependent on the schistosity and with fracturings of the cleavage. Plant remains are encountered only in the clay slates.

The clay slates are typically pelitic rocks with the size of the grain nearly 0.01 millimeter.

Under the microscope are distinguished the separate, small grains (0.03 millimeters) of quartz, feldspars, crystals of pyrite, scales of sericite, rarely grains of zircon, apatite and small needles of rutile, buried in the clayey mass. Small accumulations of kaolin and ferric hydroxides are present in the rock in large or small quantity. The constant integral part of this rock is the carbonaceous substance, which forms spot accumulations and is uniformly distributed, for the most part, in the entire mass of rock. During calcination, the carbonaceous substance burns out and the rock acquires a whitish appearance. Sometimes the carbonaceous substance collects with very fine streaks in the rock; in this case the rock acquires a micro-foliated structure. But to these

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very fine streaks usually are coordinated accumulations of ferric hydroxides; in certain cases lenticular formations of chalcedony are coordinated in them.

Within the layers, built up by the clay slates, here and there are observed lenticular streaks of fine-grained sandstones of more or less considerable size.

The variety of the described rocks is the siliceous clay slates, which are the product of secondary changes of the slates. They consist of small crystalline modifications of silicic acid (quartz, quartzine), of argillaceous substance and accumulations of kaolin. Usually veins of quartz (up to 2 millimeters thick) dissect them. The secondary change of the rock leads to sericitization, kaolinization and ferritization. All of these changes take place most intensively near the fluorspar veins.

Thus, in regard to petrographic composition, the sandstones and clay slates are characterized by the presence, besides fragments of sedimentary rock, of fragments also of minerals of igneous rocks, which indicates that the igneous rocks, undoubtedly from a group of acids (in all probability, granites or granodiorites), served as the material, in considerable degree, for their formation. The acute-angled nature of the fragments indicates that the products of the crushing of the igneous and sedimentary rocks were not carried a considerable distance. The cementation of the rocks occurred directly in the sedimentation with the products of the crushing of those same rocks.

The presence of a large quantity of plant remains in the

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rocks and the nature of the fragments permits the assumption that the deposit of them occurred under continental conditions, but more probably, that the deposit of them occurred in some closed water basins, an indication of which, in many cases, is the excellent preservation of plant remains.

The rocks of the "delyuvial'nyy" argillaceous soils. The argillaceous soil usually is an overflow of angular rubble of clay slates, sandstones and more rarely of porphyrites (the size of the fragments fluctuates within very broad limits from a fraction of a centimeter to 10-15 centimeters).

In the lower part of the slope the amount of the fragments in the composition of the "delyuvial'nyy" argillaceous soils diminishes considerably, and here they acquire columnar structure, reminiscent of the structure of loesses. Washed kaolin in the form of a prism or lens (with sizes up to 2-5 centimeters) is often present in the argillaceous soils.

B. Veinstones. Porphyrites. These rocks, in the majority of cases, are strongly altered by secondary processes. Dikes, formed by porphyrites, very highly branched, attain a thickness of tens of meters. Their invariable varieties are gray, the changed are grayish-yellow, greenish-gray or yellowish-gray. In the changed varieties there are macroscopically different phenocrysts of feldspar and hornblende.

The cleavage is thick-plated; the structure is porphyritic. The phenocrysts are represented by: hornblende, plagioclase and, rarely, by biotite.

The basic mass is finely-crystalline (the size of the grain

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is from 0.05 to 0.1 millimeter) and consists chiefly of plagioclases; dark-colored minerals (hornblende, biotite) and quartz are present in it in subordinate amount.

The following accessory minerals are present: magnetite, apatite, and, very rarely, zircon. The secondary minerals are: chlorite, epidote, calcite, sericite, kaolinite, quartz and ferric hydroxides.

Spessartites in invariable form are encountered only in one dike in the northern part of the deposit. Here they are represented by dark-gray, fine-grained rocks with lumpy structure.

The mineralogical composition of the rock is: hornblende, biotite, plagioclase, orthoclase, and quartz. The accessory minerals are: magnetite and apatite. The secondary minerals are: chlorite, calcite and sericite. The structure of the rock is characterized by the presence of a shell which was formed by sharply idiomorphic grains of hornblende, in the intervals between which are located grains of biotite, feldspar and quartz.

Under the microscope, small cavities, not exceeding 2-3 millimeters and filled with secondary minerals, are detected in the rock.

Granite-porphyry is found in the northern part of the deposit in the form of dikes with a north-west trend; it is granular, consists of quartz, orthoclase and muscovite. Of the secondary minerals, kaolinite, chlorite, sericite and ferric oxide are present in large quantity. Of the secondary minerals there are

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apatite and magnetite.

Diorite-aplite. In a microscopic study of the veinstones of the mine, aplite was not encountered; its presence in the area of the deposit is established by the chemical analyses of P. P. Pilipenko among the changed veinstones, taken directly from the lateral wall of the fluorspar vein.

Veins of quartz, which reach a thickness of 0.5-0.7 meters and a length of 5-7 meters, are encountered only in three places along the western slope of the ridge. Finer veins of quartz cut through sometimes the sedimentary rocks and porphyrites; in general their quantity is insignificant.

During a microscopic study it was found that vein quartz bears obvious traces of dynamo-metamorphism, expressed in the waviness of its fading.

The inter-relationships of the veinstones cannot be developed conclusively on the basis of a study of them only within the limits of the mine. Nevertheless, an attempt to ascertain their origin was made by Yu. I. Freyval'd [94] and N. S. Lavrovich [31].

The investigators considered the combination of described rocks as derivatives of magma, obtained as a result of ordinary magmatic fusion.

Among the vein complexes of the Turga region two groups are distinguished, which are two branches formed during the differentiation of the post-Mesozoic intrusions:

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1. "Askhistov" of granite-porphyrries, aplites and quartzitic porphyries.

2. "Diaskhistov" of porphyrites, spessarites and diorites.

The genetical connection of these two groups of rock with the Turga Range is definite. A whole series of factors indicates this.

1. The similarity or proximity of mineralogical composition of the veinstones (hornblende, plagioclase and quartzitic porphyries, diorites, spessarites and aplites).

2. The presence of streaky deposits of diorites in the peripheral part of the Turga crystalline range and the broad development in it of dikes of diorite.

3. The transition of diorites in the extreme points of contact of the dike into typical porphyrites.

4. The close and gradual transitions between the different types of porphyrites.

C. Rocks of tectonic origin. These rocks have a rather broad development within the limits of the deposit. They are representative of a different species, with breccias of the fracture consisting of fragments of clay slates, sandstones and porphyrites (the size of the fragments reaches 2-3 centimeters, sometimes more), cemented by different modifications of the silicic acid. Among them are varieties in which the cement is represented by a fine-grained mass of clay slates. Near the veins of fluorspar, fluorspar also appears in the cement of the

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breccia. Fragments of clay slate predominate in the breccia. The most interesting type of breccia is that in which the separate fragments have no bearing on one another and fuse as if in a general mass of quartzitic cement. With regard to similar breccia, encountered in fluorspar deposits in Central Asia by N. A. Smol'yaninov [54] and V. I. Sobolevskiy [58], the suggestion was advanced that its formation is connected with the processes of metasomatism.

The origin of breccia of the fracture is connected with the presence in the deposit of numerous disjunctive transgressions (faults, fractures in the contact surface of rocks of different density, breaks in the walls of folds).

In a consideration of the metamorphization of rocks of the deposit we must pause on the question of the origin of certain minerals encountered in veinstones. Such minerals are calcite, minerals of the chlorite group and selenite; Yu. I. Freyval'd and P. P. Pilipenko referred them to a series of minerals of surface origin, and, thus, the processes of metamorphism, which were connected with the formation of these, were considered by them as processes of surface erosion. A number of facts permit us to reject this assumption. The deposit of the minerals enumerated above in cavities of spessartites preceded the deposit of silicic acid in the form of quartz. But the formation of the latter took place in the period of fluorspar formation. Along the periphery of grains of hornblende, displaced by chlorite, are observed accumulations of kaolin, which also indicates the fact that the processes of chloritization of the rocks preceded processes of kaolinization. Grains of calcite sometimes are

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divided by fractures, in which occurred the deposit of limonite. The twinned bands in the grains of calcite are curved in individual cases, which indicates the fact that the tectonic movement was not completed at the time of its formation.

The indicated facts permit us to refer calcite, chlorite and selenite in veinstones to the minerals genetically connected with the processes of hydrothermal metamorphism.

If the changes of the veinstones are compared with the changes of the granodiorites of the Turga Range, with which the veins are connected genetically, then the difference in the degree of their metamorphization will be striking, inasmuch as the granodiorites of the Turga Range are changed very weakly. This remains completely incomprehensible if the point of view of the investigation referred to is accepted.

The secondary changes of the rocks of the deposit can be reduced to four basic types: (1) the dynamo-metamorphical, (2) contact-metamorphical, (3) with the assistance of hydrothermal processes, (4) connected with the processes of surface erosion.

Dynamo-metamorphical changes of the rocks of the Kalanguy deposit result in the formation in them of a system of fractures of the cleavage (the most intensive development of this has been established in the northern part of the deposit), the formation of breccia of the fracture and, finally, in the deformation of the individual minerals (the undulating dying away of quartz, the disintegration of its grains, the abnormal biaxiality of it,

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the curvature of the grains of biotite and their splitting along the edge of the displacement, and the curvature of the twinned bands of the plagioclase, calcite and others).

These changes enclosed the strata of sedimentary rocks and in a somewhat lesser degree impinged on the veinstones.

The contact-metamorphical changes in the sedimentary rocks of the deposit are coordinated to the contact with veinstones. The changes are extremely insignificant and, further, cannot be established in all cases.

These changes are considerably easier to establish in the clay slates. The latter, on contact with the veinstones, acquire brittleness (they crumble with a snap into fine rubble under a blow with a hammer), lose their dark color and become whitish or yellowish as a consequence of the burning out of the carbonaceous substance. Considerably less frequent contact changes in the clay slates take place more completely. In this case, directly on contact, at a distance of not more than 0.5 meter, the slates are converted into an aggregate of grains of quartz (hornstone). Simultaneously, in the rock, an interlaced network of fine quartzitic veinlets appears. At a certain removal of the contact, those same changes take place which were described above. The latter sometimes appear at a distance of 1-2 meters from the contact; further, usually any traces of the contact changes are lost.

The formation of nodular slates is such a rare case of contact changes in the clay slates. The changes in this case result

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in the fact that in rock appears a large quantity of small knots, formed by the compressed substance of the rock (the size of the knots does not exceed 0.1 millimeter). In the twisted nichols the little knots stand out sharply in the form of dark specks.

The changes which are connected with the participation of hydrothermal processes embrace two stages of the transformation of the rocks. The first stage, which embraced mainly the vein-stones, leads to the processes of auto-metamorphism. With the assistance of carbonic acid solutions (possibly, also with the assistance of carbonic acid gas formation) there occurred a metasomatic displacement of hornblende, biotite and feldspar by the formation in them of calcite, minerals of the chlorite group and sericite.

With the second stage of metamorphism is connected, chiefly, the processes of kaolinization, the most intensive appearance of which, naturally, is observed close to the fluorspar veins. With the processes of kaolinization are connected, undoubtedly, also the processes of silicification of the rocks of the deposit and the cementing of the breccia by silicic acid solutions. P. P. Pilipenko considers, but does not cite a reason, that the formation of siliceous solutions is connected with the liberation of silicic acid in the processes of kaolinization of the lateral rocks.

The processes of limonitization are connected with the kaolinization of the rocks and, apparently, are local variations of the kaolinization, depending on the fluctuations in the chemical composition of the enclosing rocks.

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Changes in the processes of surface erosion lead chiefly to a metasomatic change of the primary minerals of the rocks by the formation in them of chlorite, sericite, kaolinite, limonite, epidote and, partially, calcite.

Stratigraphically, the complex of sedimentary rocks of the deposit is represented by a complex alternation of layers of sandstones and clay slates of different thickness, from several centimeters to 15-20 meters. This alternation in separate localities in the northern part of the deposit becomes so frequent that the separation of the individual horizons is comparatively difficult.

The age of the sedimentary strata was solved by I. Ye. Khudyeyev [71]. The flora and fauna collected by him leaves no doubt that the sedimentary strata of the deposit pertains to the Middle Jurassic Period.

In the southern part of the deposit, flora was collected which V. N. Prinada determines thus: Czekanowskia rigida Heer, Cladophlebis sp., close to Cl. haiburnensis, Ginkgo of the group Ginkgo lepida, Pityophillum Nordenskioldii (Leth) Sow., Cladophlebis kamenkensis Thomas.

These forms also confirm with certainty the Jurassic age of the sedimentary rock of the deposit.

The presence among the specimens of Cl. haiburnensis, which is characteristic only of the Lower and Middle Jurassic, determines the upper limits of the age of the strata. Regarding the last form Cladophlebis kamenkensis Thomas, as is known, is described by Thomas for the "batskiy" and, partially, possibly for the Lower Callovian

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layers of the Donets Basin, which permits us to define more accurately, apparently, the determination of the strata of sedimentary rocks of the deposit.

As has already been indicated, the Jurassic strata is broken through by a series of vein bodies, the age of which is determined as post-Jurassic, and it is not possible to determine it more closely.

The tectonics of the Kalanguy deposit is distinguished by cleavage. The basic difficulty, which arises in deciphering the structure of the deposit, results in the absence, virtually, of characteristic horizons and in the rather bad erosion of the ridge. Only the careful tracing of more or less sharply expressed strata, which are built up by those or other rocks, and the presence of a large amount of pit mining permits the question of the tectonics of the deposit to be decided.

Elements of folded transgressions. The strata of Jurassic rocks occurs in the form of strips of sandstones and clay slates between the strata, stretched out almost in a latitudinal direction with a trend from the north-east 70 degrees to the south-west 100-105 degrees / 70-80 degrees to the north and south.

In the northern part of the deposit the dip becomes almost exclusively northern, the rocks were exposed to the greatest degree of shearing and developed a network of fractures. The deviation of the northern dip, which is sometimes observed, and the strong shearing of the rocks is explained, undoubtedly, by the cleavage of the folded transgression.

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The system of described folds, generally, is almost of a latitudinal trend (80-115 degrees), is complicated by folds of lesser amplitude (2-5 meters). An interesting form of folded transgression, also, are the deflections of folds in the trend (the transverse crimping of the seams). The range of these deflections fluctuates from 0.5 to several meters. The deflection develops in one degree or another for the seams of the sedimentary rocks and in the dip (the longitudinal crimping). In addition to the folded transgressions, the rocks in the separate lamina were exposed to finer transgressions, which are expressed in the formation in them of folding. These phenomena of folding, as also the phenomena of fine transverse crimping, is coordinated exclusively to the clay slates.

Disjunctive transgressions also are distinguished by considerable cleavage; among them can be developed five groups. To the first group of transgressions pertains the faults which were obtained on the contact of rocks of different density -- precisely the sandstones and clay slates.

Such a fault is stated in the under side of the deposit, where it is accompanied for a great distance by the breccias of the fracture and breccia-like rocks. The formation of these faults occurred, apparently, from the formation of the transverse crimping of the seams, inasmuch as the zone of the fault, represented by the breccia, is curved along the trend.

The second system of fractures with a trend close to the latitudinal (north-east 70 degrees, south-east 100 degrees) cuts

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the rocks at an acute angle to the trend of folds.

These fractures do not cross the fluorspar veins, do not impinge on the structure of the ore substance, and the large part of the fractures is achieved by the veinstones, fragments of which are encountered among the breccia, which accompanies the vein substance. The fractures have their principal development in the sandstones.

The third system of fractures has a trend close to the meridional (north-south, north-east 25-30 degrees); to it pertains the thick zone of the crushing of the rocks, which accompany the fluorspar vein (the main fault of the Kalanguy deposit). To this same system of fractures belongs the fault of almost meridional direction, in which occurred the dislocation of the sandstones of the marking horizon of the suspended side of the vein.

The structure of the main meridional fracture of the disintegration of the rocks, which is a transverse fault (relative to the trends of the rocks), in the given pit mines and on the basis of observations, is depicted in the following form. The fault zone, with a maximum thickness up to 15-20 meters, which is represented by various kinds of breccias of the fracture, cuts the stratum of sedimentary rocks transversely of its trend and has a trend strictly meridional to the south and to the north, somewhat deflected to the north-east up to 10-15 degrees. The zone that is drawn out in this manner is unbroken the entire length.

The length of the fault zone is established as nearly 900

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meters. The northern extension of it is determined by the dislocation of the individual horizons of sandstones and clay slates. Finally, its termination in the north is established by the pit minings. The fault here is completed by fan-shaped cleavage ("horse tail").

The surfaces of the sliding of the faults of the zone, formed by huge "zerkalo" of the sliding and which is detected for an extent of several tens of meters and less, as also the fault zone, are curved along the trend; owing to this their trend in individual places decreases from south-east 175 degrees to north-east 5-10-32 degrees. The general dip of all these surfaces of sliding are to the east at an angle of 55-75-80 degrees. Dislocations along the fault zone occurred repeatedly and over a rather lengthy period of time.

In connection with this, the disintegrations of the "zerkalo" of the sliding, which formed along the thick zone, sometimes are observed in an amount of two or more, located parallelly, but which are not concurrent with each other.

The variance of the parallel surfaces of the sliding is insignificant and fluctuates within the limits of several centimeters. Thus, the fault bears, undoubtedly, a graduated character. The presence of surfaces of sliding also in the fluorspar indicates the presence of post-mineral transgression of the described system.

On the surfaces of sliding, forming angles of 5 to 25 degrees with the direction of dip of the fault, deep parallel furrows pass through, which indicates that the dislocation of the

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rocks took place to the south at some angle to the dip of the fracture.

The marking horizon of sandstones which is encountered on both sides of the fault zone appeared on the under side displaced to the south. The layers adjoining the fault clearly bend to the south, obviously, under the influence of the stress of the under side, which was displaced toward the south. The series of faults which prevail in the northern part of the under side -- of an almost latitudinal trend -- confirms the break in this part of the under side during its faulting.

Summarizing the account regarding the main fault of the Kalanguy deposit, it is possible to define it as a steeply dipping underthrust, where the under side is dislocated to the south under the suspended side at a small angle of 5-25 degrees to the direction of its dip.

The complete dislocation of the rocks is determined according to the overall dislocation of the seams of the marking horizon of sandstones and according to the direction of the dislocation (which forms, on the average, an angle of 15 degrees), which amounts to nearly 140 meters, approximately.

Tectonic transgressions, which accompany the intrusion of veinstones, occurred in the fractures, with a trend close to the latitudinal (at a sharp angle to the trend of the folds), but, in part, the veins took root also in the surfaces of the strata of the containing rock. Their intrusion was accompanied also by

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the formation in the containing rocks of a system of small horizontal shiftings of a local character. Such a dislocation is excellently visible in the south part of the deposit, where the small layer of clay slates, which were changed upon contact, adjoining the dike of porphyrites, sustains perpendicularly to the short dislocations with an amplitude of 1-2 meters. With the intrusion of veinstones is connected also the development of extremely intensive fracturing of the rock near the vein.

Observations over the fractures in the sedimentary strata, which passes near the vein of fluorspar, indicated the presence of them in one square meter in a quantity of 3 to 10.

The thickness of the fractures fluctuates from a hair to 2-3 millimeters and most often in 0.3-0.4 millimeters. Slightly dipping fractures usually are iron-bearing, but steeply dipping fractures contain kaolin or pulverized fluorspar. There are no fractures completely free from filling up with some substance.

The most widespread direction of fractures is north-east 33 degrees /74 degrees, but in lesser quantity fractures are encountered with a trend north-west 349 degrees /68 degrees; north-east 88 degrees /67 degrees and a fracturing in insignificant amount is present with a trend north-east 80 degrees /36 degrees; north-east 66 degrees /74 degrees. The figures of the trends are cited as the average of several hundred measurements.

As already mentioned above, the vein of fluorspar is coordinated to the tectonic fracture of the fault-dislocation type with a trend to the south meridian and to the north with a deviation

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to the north-east 10-25 degrees. The dip of the vein is east at an angle of 50 to 75 degrees, with an average of 62-63 degrees. The extent of the vein zone reaches nearly 900 meters. To the south, within the limits of pit No. 5 and trench No. 1, the vein thins out in a natural dying out of the fractures of disintegration. In the northern extremity it rather abruptly breaks and further alternates with an entire series of fine veins and veinlets (up to 11 in amount), which, apparently, is explained by the break of the fractures enclosing ore substance with the transverse fault still up to the conclusion of fluorspar formation. The most northerly part of this point, approximately for 500 meters, on the same eastern side of the Kalanguy River, are found again several short veinlets of fluorspar, with a thickness from several centimeters up to 0.4 meter. In contrast to the main vein, they possess a trend approaching the latitudinal - north-east 60 - 70 degrees, with a dip both to the north and also to the south, at an angle of 35-70 degrees. According to conditions of stratification, in composition and structure they are similar to the main vein, but are insignificant in size and therefore do not merit attention as an industrial object.

The depth of the main vein along the dip has been determined by prospectings (drill holes) up to 173.29 meters on the vertical, calculating from the higher hypsometric point of the deposit.

In the continuance of the vein zone, along the entire length of the fracture of disintegration, the fluorspar is not a continuous substance, but is dissected also along the trend

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and along the dip by the so-called narrowings in its length of 5 to 20 meters, rarely more. In places, where there are narrowings, the main zone is represented either by breccia of the lateral enclosing rocks, which are cemented by silicic acid or fluorspar, or was filled with veinstones, described above, but principally by porphyrites. In places where there are narrowings, the fluorspar is preserved in the form of insignificant veinlets of a thickness from 0.15 to 0.2 meter, and often disappear again. A characteristic peculiarity of the narrowings is their tendency toward exposure along the dip and the presence near them of a small (10-15 degrees) incline to the north. The majority of narrowings is coordinated to the northern part of the deposit and in relation to the length of the vein zone they build up in horizons: gallery No. 2 - 11 percent, pit No. 1 - 20 percent, gallery No. 1 - 0 percent and gallery No. 3 - 11 percent.

Besides the small narrowings, there exist the so-called main narrowing, which divides the deposit into two almost equal parts; it is located in a section of mine No. 1 and runs approximately 90 meters along the trend.

The thickness of the zone of crushing, as a maximum, reaches 10-12 and rarely 20 meters; the thickness of the vein of fluorspar fluctuates within the range of several centimeters to 6.10 meters. The latter figure is the maximum for the deposit. Thicknesses of 1 to 2 meters, on the average, prevail; in the open pit mining, nearly 1.6 meters. Bulges of the vein

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(maximum thickness) are coordinated to places of most intensive crushing, to which the sandstones were subjected most readily of all. Owing to the non-coincidence of the rocks of the suspended side and the underside, the bulges between them (in view of the presence of a fault displacement) are almost always one-sided.

The thickness in the bore holes is cited below in Table 3.

Judging by the data of the bore holes, the ore substance has a tendency toward increasing in thickness; on the average, in eight holes it amounts to nearly 3 meters (2.95 meters). Near the surface the vein is complex in structure, and the interval between its separate parts is insignificant, but in depth, in almost all of the holes, it is dissected into two, three and even four veinlets with intervals between them, which occasionally amount to 2-3 meters and more (hole No.5). This, finally, will hamper the exploitation of fluorspar in the deep horizons.

Changes on the side rocks occurred in the direction of kaolinization, sericitization, limonitization, silicification and fluoritization.

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Table 3

No of Hole	Depth of Cutting of Vein Zone in Meters	Actual Thickness of Fluorspar in Meters	Character of the Fluorspar Vein
1	75.0	3.46	3 veinlets
2	100.20	5.20	1 vein
3	65.43	5.30	2 veinlets
4	Fluorspar not encountered		
5	80.41	0.88	2 veinlets
6	170.29	1.80	4 veinlets
7	105.52	0.90	3 veinlets
8	180.82	0.80	2 veinlets
9	98.75	4.90	1 vein

The first two processes are most sharply expressed in the suspended side and especially in the sandstones, where the feldspar in places is entirely kaolinized. Silicification is coordinated chiefly to the suspended* (*Errata: Page 41, Line 16 from the top; "to the suspended" should read "to the under") side and is connected with the formation of chalcedony and hornstone. Silicic acid plays a large role in the cementation of the tectonic breccia. Limonitization impinged both on the suspended and also on the under side, but in greater degree on the first. Fluoritization covered a considerable zone (up to 7 - 8 meters) on both sides of the fluorspar vein and is represented either by the filling up of the minute fracturing with fluorspar, or the

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displacement of minerals in the rocks, which were destroyed by kaolinization or sericitization.

The fluorspar of the Kalanguy deposit possesses chiefly a light-rose, smoke-colored, light-cream-colored, light-violet and green color (northern, non-commercial part of the deposit). Colorless varieties are encountered.

In its external form the fluorspar is divided into radially-radiating, shelly, concentric concretions (cockades); it is ribbon-columnar, ribbon-symmetrical and finely-crystalline.

The radially-radiating concretion type, relatively widespread, is coordinated to the central part of the vein, to the zone of greatest thickness of the ore substance. The concretions are oval, spherical and ellipsoidal in form and in diameter reach a maximum of 1 meter, often 0.3 - 0.4 - 0.5 meter. In the center of each concretion are angular or round fragments, of different sizes, of the enclosing rocks (principally sandstones and clay slates) or fragments of fluorspar. Sometimes two centers exist, and primarily, the growth takes place around each of them separately, and further, as if around one center. The growth of the concretion occurs concentrically, owing to which all of them have a clearly expressed shelly structure; the central shells, therefore, possess great thickness. Each shell consists of radially located, elongated columns, often with a clear hexahedral form, at the end of the column changing into an incompletely developed cube. The thickness of the shell reaches 10-15 centimeters in the section of the column of a

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maximum up to 4 - 5 millimeters. Frequently, a tree-like structure is encountered in the individual shells. The latter often are singled out one from the others by fine layers (0.1 - 0.5 - 1 millimeters) of a kaolin-fluorspar aggregate, cemented by silicic acid. Sometimes an increase in the intensity of the color of the fluorite toward the surface of the concretion is observed.

The ribbon-columnar type is similar in its structure to the preceding, but differs by the parallel location of the separate columns. It is coordinated to the periphery of the vein substance or continuously joins it at the place of little thickness, and is coordinated to the breccias where the fluorite encloses separate fragments of breccia. The ribbon-symmetrical, as also the preceding, is coordinated either to the periphery of the vein or continuously fills up the whole fracture, as, for example, in gallery No 1 and 2 and in the northern part of gallery No 3. In distinction from the preceding, it does not have a clearly expressed columnarity, although the bands stand out as a result of the difference in the intensity of the color. The finely-crystalline or saccharoidal fluorspar consists of white oval or tubular, fine crystals of a fraction up to 1 millimeter in diameter. There are gradual transitions to the columnar type. This form of fluorspar is encountered in small quantity to the north of the deposit beyond the limits of the mine. But here, sometimes, are encountered druses of regularly developed cubes of green color.

The fluorspar in the vein is the leading mineral and

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pyrite and marcasite (in the relatively deep horizons) in the form of separate crystals, modifications of silicic acid (excluding quartz), ferrous hydroxides, kaolin and calcite are encountered only in insignificant quantity.

Qualitative character of fluorspar. Above (see page 16) is brought out the average of the content of CaF_2 and SiO_2 in the separate horizons of the working mines. Analyses of a sample in the bore holes showed the following results (Table 4).

Table 4

No of Hole	Interval on the Incline in Meters	Content in percent				Remarks
		SiO_2	CaF_2	S	Fe	
5	97.70-98.48	3.66	85.63	1.84	5.57	The average con- tent CaF_2 in holes
5	98.48 - 98.78	5.20	84.86	1.48	4.49	
6	170.29 - 171.49	0.77	97.74	0.09	0.06	No 1, 2 and 3 - 84 percent
6	141.40 - 171.10	38.58	45.00	0.05	1.99	
6	175.05 - 176.36	12.48	82.23	0.05	0.19	
6	149.25 - 179.95	3.01	90.07	0.07	2.21	
7	105.52 - 105.82	0.36	96.84	0.02	0.03	
7	107.06 - 107.21	4.28	92.84	0.03	0.04	
7	107.49 - 108.82	2.32	95.50	0.30	0.06	
7	108.82 - 109.40	20.18	73.55	0.25	0.28	
8	108.82 - 181.77	7.10	86.99	----	----	
8	181.97 - 182.27	3.43	93.59	----	----	
8	182.80 - 182.48	55.82	21.90	----	----	

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The content of CaF_2 in the pit mines fluctuates within the limits of 62.61 to 98.51 percent. The figures 78 - 85 per cent predominate.

Along the trend, the southern part of the deposit possesses a higher quality fluorspar than the northern. Possible changes in the quality of the fluorspar with the depth are indicated on page 16.

The fluorspar possesses considerable toughness, especially in the northern part of the deposit; during extraction a lumpy material from 3 - 5 centimeters and up to 0.3 - 0.4 meters in diameter is obtained.

Thus, on the basis of its mass, the fluorspar, with changes in content only by means of hand sorting, can satisfy, according to its quantity, ferrous metallurgy and only certain branches of the chemical industry, and then only in insignificant quantity. Geological-prospecting work at the deposit during the period 1931 - 1935 was conducted by the Far Eastern Expedition of the All-Union Institute of Mineral Raw Material. The following changes, which have taken place since that time in the reserves of fluorspar, are given in Table 5.

Table 5

Year	Categories of Reserves in 1000's meters				Amount
	A ₂	B	C ₁	C ₂	
1931	25.0	44	147.00	-	216.60
1935	20.0	293.0	220.0	58.0	591.0

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On January 1, 1933, the Central Committee on Reserves GGU confirmed the following figures: A_2 24,700 tons; B - 162,000 tons; C_1 - 241,000 tons. In all - 457,400 tons.

At the present time (1936), gallery No. 2 is worked out completely, pit No 1 and gallery No 1 are finishing working and cleaning operations are conducted chiefly in gallery No 3. In the central part of the deposit, a shaft runs through, which must be brought into operation in 1936. Prospecting pit No 6 goes far into and is reconstructed in the shaft in all the operations of the southern section of the deposit (southern gallery No 3). Prospecting operations on the surface in the summertime play a fairly big role, and in individual months by this method up to 300-400 tons are extracted. Owing to the fact that the dressing of the fluor-spar ore is carried out only by the method of manual sorting, a considerable amount of fines goes onto the dump. In 1933, experiments showed that 443 tons of ore, 225.1 tons, ranging in size from 25 millimeters and less, did not undergo sorting. Now at the mine there was accumulated up to 60 thousand tons of fines with a content of 50 to 60 percent CaF_2 .

Taming Deposit. The deposit, discovered in 1931 and worked since 1932, is located 3.5 kilometers on a direct line with the direction north-east 48 degrees from the Kalanguy deposit. The veins, three in number, are situated on two volcanic mounds - the Taming I and Taming II. The latter is dissected by a ravine nearly 400 meters wide. In geo-morphological and hydro-graphical relationships this deposit is

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similar to the Kalanguy. The shattering and dislocation of the rocks occurred so strongly that all slopes up to the very summit of the mounds are covered with detritus, leaving an insignificant amount of the outcropping of original rocks. Particularly, benches of considerable sizes are achieved at Taming II, where, owing to the sloping dip of the ore body (40 - 45 degrees on the average) on the side of the slope and the slight toughness of the fluorspar (insignificant content of silicic acid) the significant upper part of the fluorspar vein is crushed and washed down.

In regard to geology, the region of the deposit is a continuation of the Kalanguy and, naturally, similar to it.

The sedimentary-metamorphic stratum ($J_1 + J_2$) has a trend north-east 55 - 60 - 67 degrees $\angle$ 60 - 80 degrees north and south, and if the sandstones and clay slates were located directly at Kalanguy in more or less identical quantities, then here, at the Taming deposit, the slates predominate over the sandstones, and as material, which yields less to disjunctive transgression, yielded short, narrow lines of fractures. Besides these rocks, small sections at Taming I and II contain Jurassic basalt [basal ?] conglomerates, which underlie the stratum described above and transgressively lean on the Paleozoic granites (Taming Range). The conglomerate consists of an average amount of fragments of clay slates, feldspar, quartz and granite gravel with sand-clay cement and with the remains of Jurassic fauna of the upper Liassic. These con-

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glomerates develop downwards into rose-yellow, coarse-grained, granitized conglomerate-gneiss, which, in structural form and mineralogical composition is similar to the granites which lie under it.

Beyond the limits of the described sedimentary-metamorphic stratum, to the north-west, is located the so-called Taming granite range. The granite is average-grained and is represented by the weakly-micaceous variety of grayish-yellow color. It has a compact structure and in rare cases, in the parallel arrangement of the mica, passes over into the schistous variety (with latitudinal direction). Under the microscope the granite consists of feldspars, which are represented by an allotriomorphic microcline, in relation to the plagioclase, with a characteristic lattice structure and with the plagioclase predominating over the first. The latter were exposed more to the processes of disintegration. The minerals of the second are quartz, biotite in lesser quantity, and epidote and chlorite of the secondarily developed minerals are encountered. Possessing a hypidiomorphic structure, sometimes the granite, owing to the coarse deposits of plagioclase, passes over into a porphyritic.

The Taminga, being an unbroken geological continuation of the Kalanguy, possesses all those same elements of folded and disjunctive dislocation which are characteristic also for the latter. The veins of fluorspar both at Taminga I and also at Taminga II cut almost transversely the trend of the sedimentary stratum, which is principally clay slates, owing to which they

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strongly silicified, but in the transition of the dip of the vein body from hollow into abrupt silicification ceases to be characteristic only for the under side and is extended to the suspended side also. Among the chalcedony the presence of irregular inclusions of plagioclastic porphyrites is observed on both sides. Always there, where there are local narrowings of the vein of fluorspar or tapering out of it, the greatest development is observed of the porphyrites in the complete absence of modifications of silicic acid and fluorspar, and the porphyrites completely fill the fractures of the break.

Characteristic is the relation of the thickness of the vein to the steepness of its dip, which results in the fact that the steeper the dip of the vein the greater its thickness and vice versa.

The structure of the ore body and its mineralogical composition is almost analogous to the Kalanguy deposit. The quality of the fluorspar, in comparison with that of Kalanguy, is higher on account of the insignificant content in the fluorspar of silicic acid and the inclusion of barren rock. Below, in Table 6, chemical analyses of fluorspar are brought out, conducted by the analytical laboratory of the IMS.

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Table 6

Main Vein	Name of the Development	CaF ₂	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	MgO	H ₂ O
	Trenches	91.24	2.65	-	-	-	-
Taminga I	"	89.12	5.56	-	-	-	-
	Gallery 2	89.12	5.60	-	-	-	-
	"	94.00	1.47	-	-	-	-
	"	78.46	6.86	-	-	-	-
	Gallery 1	91.24	2.65	-	-	-	-
	"	86.67	3.88	-	-	-	-
Taminga II	"	75.48	4.09	-	-	-	-
	"	76.36	12.97	-	-	-	-
	Trenches	97.64	0.5	1.19	0.57	0.58	0.08
	"	99.06	0.00	0.28	0.23	0.47	0.06
	"	99.80	0.00	0.14	0.15	2.28	0.02

Such a low content of SiO₂ in the fluorspar, especially in Taminga II, where silicic acid is completely absent in places, is the reason for the insignificant toughness of the fluorspar and during the production of cleaning work a considerable quantity of fines is obtained. As an example, there should be calculated in the vein a yield of fines up to 40 percent (up to 1 - 2 centimeters in diameter) of the whole reserve. A chemical analysis of an average sample of fines showed the content of CaF₂ to be 88.84 percent and SiO₂ to be 3.08 percent.

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Avoiding losses of fluorspar during extraction is possible only by means of effecting the most careful sorting.

At the present time (1936), the operation of Taminga I is effected by underground workings of pit No 4, and Taminga II by gallery No 2, which passes through along the trend and with slopes along the dip, and No 3, which is laid (in the center of the vein) transversely of the trend with crosscuts along the latter on both sides (to the north-east and south-west). The average depth of the operation reaches 50 meters. The mine yielded in recent years (1932-1935) 2 - 4 thousand of commodity production per year, which goes for ferrous metallurgy and for certain kinds of chemical industry.

On the mound Taminga I, to the west of the main vein (300-400 meters), are located two veins of a north-east trend 15 - 20 degrees $\angle$ 60 degrees east. The veins in essence represent breccia of lateral rocks, cemented by vein minerals, and in their mineralogical composition, para-genetical relationships and nature of the fluorspar are identical to the Abagaytuy deposit. The fluorspar is coarsely-crystalline, compact, rarely ribbon-like, green, sometimes violet or colorless. In considerable quantity, hornstone and comb-like quartz are present in intimate coalescence with the fluorspar.

Owing to the insignificant reserves and the thickness of the veins (up to 0.6 meters, they were exhausted in 1934- 1935 by prospectors.

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The reserve of fluorspar in the main vein on January 1, 1933, is shown in Table 7.

TABLE 7

Main Vein	Reserves in Categories $A_2 + B + C$ in thousands of tons	Note
Taminga I	18	Reserve in Category A_2 at the beginning of 1934 was almost exhausted.
Taminga II	22	

On January 1, 1936, the reserve comprises:

Taminga I - $B + C$ 6 thousand tons

Taminga II - $B + C$ 12 thousand tons

Ninth Friday Deposit is located 5 kilometers to the north-east of the Kalanguy mine and is coordinated to the mound of that same name. The mound forms the left slope of the Turga River and consists of three spurs of the north-east trend, which converge in the north near the highest point, which is 280 meters above the level of the river and over 1 kilometer above sea level.

Erosional processes formed a well-expressed deep

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ravine. The granites and granodiorites which are present in the north and east block the further development of the ravine. The north-east direction of the spurs is connected with the three quartzitic-fluorspar veins - more accurately, with their thick zones of silicification, which run through in one to each branch in that same direction.

The area of the deposit is built up principally of sedimentary-metamorphic strata of the Jurassic Age (J_2), consisting of arkose and graywacke sandstones and clay slates, which broke through to the north and east with granites and granodiorites (Turga Range). The trend of the stratum is north-west 300-320 degrees $\angle$ 48 - 70 - 78 north and south, but chiefly with a dip to the south.

On contact with the granites the clay slates are changed into chistolitic and, in places, into biotitic and graphitized gneisses.

Of the veinstones, porphyry-like, rosy, fine-grained aplites, quartzitic diorites and porphyrites are present.

The porphyrites have a wide distribution, and in structure and mineralogical composition are encountered from purely dioritic to albitic. Among the strictly porphyrites there are several varieties: with micro-crystalline and felsitic basic mass and with phenocrysts, represented solely by the plagioclases and with coarser crystalline mass, in which the main role is played by quartz and feldspar (the first in subordinate quantity).

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Their chief varieties are the hornblende, plagioclase and albitophyry, and quartzitic porphyrites; there are also quartzitic porphyries.

In the middle of the sedimentary-metamorphic stratum the veins are almost stratified, but when accompanied by veins of fluorspar (chiefly on the under side) they have the same direction as the latter.

The fluorspar in the deposit is represented by numerous veinlets, thus by the three veins of north-east trend with a dip to the east at an angle of 50 to 90 degrees. The trend of the veins are: west vein - north-east 45 degrees; middle vein - north-east 30 degrees; and east vein - 30 degrees. All three veins are exposed to considerable erosion and in the depressed places of the relief, where prospecting has revealed the deepest horizons of the ore body, the displacement and substitution of fluorspar by quartz is observed. Owing to this, all three veins are not of a uniform substance, and consist of separate parts, dissected among themselves by depressions in the relief. This phenomenon is characteristic especially for the western vein.

The western vein possesses fluorite, which approaches the high-temperature type with compact-crystalline structure and with green or rose-violet color. In places is observed a ribbon-like, symmetrical structure of the vein; in such a case it reaches a maximum thickness for the deposit (up to 1 - 1.2 meters). In the vein body a considerable quantity of breccia of clay slate is present, which is cemented by quartz

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or fluorspar. Silicic Acid in the form of quartz or chalcedony is coordinated in the main mass to the under side, and also cuts through the fluorspar by means of veins or veinlets.

The porphyrites described above are a constant companion of the vein zone and is a stratum of slight thickness (up to 0.2 meter) lying on the under side. In the latter are clearly expressed surfaces of sliding in the porphyrites and in the sedimentary-metamorphic stratum. The lateral rocks, in addition to silicification, were exposed to sericitization.

The middle vein (with a sharp or vertical dip) consists of compact-crystalline and symmetrical-ribbon fluorspar; on the trend a division of the vein for a short distance into two branches with an interval between them of 3 - 4 meters is observed. Of the veins, the western approximates in nature the preceding; the eastern is similar to the veins of the Kalanguy deposit. The casings of the veins are silicified and kaolinized, especially the suspended side.

The eastern vein is built up by fluorspar of the high-temperature type, with a weak rose color, or is colorless. The kaolinization of the lateral rocks is considerable.

Thus, from west to east the transition of the vein substances is clearly observed in the structure of the fluorspar to a mineralogical composition and to changes of the lateral rocks from high-temperature to low-temperature type. All three veins are coordinated to the faults

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which cut the sedimentary stratum almost transversely of the trend.

The thickness of the veins fluctuates within the range of 0.1 to 1.5 meters, an average of nearly 0.5 meter. The length of the sections of the veins with commercial reserves is from 30 to 70 meters.

The reserves in all of the deposits on January 1, 1932 was expressed by the following figures in category A₂ + B - 13 thousand tons and C - 7 thousand tons.

The deposit was discovered in 1931, and since the summer of 1932 had begun to be developed. Operations are conducted only during the summer period by prospectors by means of the open-pit method; the amount extracted does not exceed 300 - 400 tons per year. Up to 1935 only the western vein was developed.

The Zmeyev deposit adjoins the preceding directly to the south-east and is coordinated to the mounds I Zmeyev - western and eastern - and II Zmeyev.

On the western mound I Zmeyev, of three prospecting trenches which were fixed for a distance of nearly 40 meters, only one veinlet of fluorspar, of emerald color and about 0.3 meter thick, was encountered among the silicified clay slates (J₁ + J₂). In them numerous cavities are present, in which are encountered fine semi-transparent, colorless octa-

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hedral crystals. On the eastern mound of the trench there is also revealed an insignificant veinlet with a trend north-west 310 degrees $\angle$ 55 degrees west. On mound II Zmeyev, insignificant veinlets of fluorspar are present. The deposit does not have industrial importance.

The Ol'gin (Otsoluy) deposit was discovered in the summer of 1934; at the end of the same year the exploitation of it was begun. The deposit is located 12 kilometers to the south-east of Kalanguy and 7 kilometers in that same direction from the Ninth Friday deposit. The closest village is the large Turga settlement, which is situated 9 kilometers to the north-west. This deposit is connected with the Kalanguy by a field road, which is completely accessible for auto-freight traffic at any time of the year.

The veins of fluorspar are located at the top of the Otsoluy Ravine, which falls into the valley of the Syraya Antiya River from the right side.

Here the valley of the river reaches a width of nearly 1 kilometer; its right slope has a smooth, sloping contour, its left is abrupt and mountainous. The river itself is pressed to the left side and is approximately 2 kilometers from the deposit.

At the time of maximum thawing of the perpetual frost, the high points of the relief are swamped (the frost is a water-resistant horizon), and on top of the ravines springs form sporadically. But in general the region of the deposit as far as the thawing of the perpetual frost of the upper horizons

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or in case of a dry spring and summer is not guaranteed water, and the supplying of the mine with water is difficult. During the winter period, with the freezing of the river at the bottom, the question of water supply is still more complicated.

The area of the deposit adjoins from the south to the Turga intrusive range and is built up by sedimentary and crystalline rocks. The first are represented by meta-morphic clay slates, sandstones and conglomerates of Jurassic age. In places of disjunctive dislocation, they form breccia (especially the clay slates), cemented by quartz and chalcedony. The crystalline rocks are represented by granodiorites with their derivatives in the form of veins of quartz, granodiorite, hornblende and plagioclase porphyrites.

The strata of clay slates (J_1) is diffused to the north-east and partially to the north of the area of the deposit.

The area of the deposit is built up by a sandy-clay strata (J_2) with a predominance of the clay slates over the sandstones. Conglomerates (J_3) are found only in one place, namely in the south-west corner of the deposit. They are coordinated to the syncline which was formed by Middle Jurassic sedimentation.

The whole Jurassic stratum is intensively collected into short folds of a north-west trend with a dip to the

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north and south at an angle of 40 to 80 degrees, most often of all at 60 - 70 degrees. The direction of the dip is principally north; owing to this the throwing back of the folds to the south is often observed.

The veinstones usually are represented by short dikes, which cut the sedimentary stratum at an acute angle. The veins of fluorspar always are accompanied by porphyrites, which have a trend conforming to that of the veins of fluorspar. The chief mass of porphyrites is coordinated to the under side, where it reaches a thickness of 6 - 7 meters.

In contrast to the overwhelming majority of deposits of fluorspar of Eastern Trans-Baikalia, the Ol'gin is represented not by one vein body but by two fluorspar-bearing zones of different trend. The first zone runs in the direction of north-east 75 - 80 degrees, that is, it approximates to the latitudinal. For the Turga group of deposits this trend is exceptional. The second zone has a trend north-west 340 - 345 degrees and north-east 15 - 20 degrees, that is, approximating to the meridional direction. This zone is represented by five veins; of them only a part has commercial importance.

The zone of latitudinal direction does not represent a continuous vein body, neither in direction nor in dip; the thickness of it varies exceptionally. Of almost half a kilometer in length, only the western part of the vein, with a length of about 230 - 260 meters, has commercial value. A

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characteristic factor, having importance for future prospecting, is the fact that this commercial part of the zone at its eastern end shifts the trend to the north-east 50 - 55 degrees in a general dip of the whole zone $\angle$ 60 -65 degrees to the south and up to 90 degrees. The thickness of the commercial part of the vein fluctuates within the range of 0.40 to 1.70 meters in an average of 0.6 - 0.7 meter.

The thickness of the non-commercial part of the vein (the eastern) fluctuates from 0.10 to 0.25 meter.

In its structure the vein for the most part is not a compact substance, inasmuch as for a considerable extent the central part of it is filled with quartz or chalcedony, and in places by a fine clayey material with a large quantity of ferrous oxide and with an inclusion of fine fragments of fluor-spar. The enclosing rocks in the suspended side partially are kaolinized in the fracturings, but in the under side are silicified and have a well-expressed surface of sliding.

The fluorspar in its nature is close to the Abagaytuy, has a compact-crystalline or symmetrical-ribbon-like structure, which has a slightly columnar development. The fluorspar is grayish-green, grayish-violet white or colorless.

The fluorspar is distinguished by its high quality. The content of CaF_2 fluctuates within the limits of 90.17 to 97.9 per cent, SiO_2 from 1.11 to 5.44 per cent. With depth, apparently, the content of SiO_2 increases, as is indicated by the results of analyses in hole No 2 (Table 8).

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Table 8

No	Interval in Meters	Content Per cent		Notes
		CaF ₂	SiO ₂	
1	30.60 - 30.70	97.11	2.36	Suspended part of vein
2	30.70 - 30.91	58.62	37.25	Central
3	30.91 - 31.19	61.68	36.60	Under

From the data cited it is seen that the silicification is increased considerably toward the under side.

The prospecting which was conducted indicated the in-significance of the extent of the commercial part of the vein in the dip (Table 9).

Table 9

No	Interval in Meters	Character of the Vein Zone
1	38.69 - 40.01	Chalcedony with veinlets of fluorspar
2	30.60 - 31.19	Fluorspar
3	40.56 - 42.55	Veinlets of Fluorspar
4	25.90 - 27.62	Fluorspar

Thus, the fluorspar runs only up to a depth of 25 - 30

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meters (on the dip).

Reserves are expressed by the following figures (up to November 1, 1935, according to category): B - 11,000 tons, C₁ - 3,500 tons, C₂ - 1,000 tons. Operational work up to the end of 1935 was carried out by the open pit method; at the present time a gallery runs through transversely to the trend, and the fluorspar is dug up from two crosscuts, the western and the eastern.

The veins (four in number) of the zone of meridional direction are distinguished by considerable thickness, with a maximum up to 0.6 - 0.7 meter, and with a short length, up to 30 - 50 meters.

The fluorspar is of the low-temperature type of weakly-cream-colored or weak violet color with inclusions of fragments of barren rocks. In places the fluorspar alternates with breccia of the enclosing rocks, which are cemented by the fluorspar. The lateral rocks are kaolinized in considerable degree. Owing to the small extent in trend and dip (up to 10 - 15 meters) the reserves are insignificant, and the mining is done by prospectors by the open-pit method.

The Duturul deposit is located on the right side of the summit of the ravine of that same name, approximately 5 kilometers to the east of the Bol'shoy Sektuy. Here the presence of fluorspar is established; it is close to the high-temperature type and is very similar to the fluorspar of the Solonech deposit.

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The deposit merits the organization of preliminary prospecting.

The Kovrizhka deposit is located in the valley of the Turga River directly to the north north-east of the village of Turga and is coordinated to a small mound, built up by coarse-grained, crystalline, Paleozoic limestones, which burst through in intrusions of granodiorites (Turga Range). In a north-eastern direction the limestones are cut through by veins of quartz with rare inclusions of crystals of fluorite of green and violet colors. One of the veins in the trend north-east 60 - 70 degrees passes over from quartzitic vein to a fluorspar vein, with a thickness of nearly 0.5 meter. The deposit does not have commercial importance.

The Byrykchin deposit is located 5 - 6 kilometers to the north-east of the village of Turga and is situated on the mound of the same name. The fluorspar is connected with veins of quartz, which dissect the granite.

The fluorspar is cream-colored and is similar in structure to the abagaytuy. In places there is an indistinctly expressed columnar structure. The thickness of the veinlets does not exceed several centimeters. The deposit does not have commercial significance.

THE ARGUN' GROUP OF DEPOSITS

The deposits of this group are located on the left tributary of the Argun' River and are scattered over a con-

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siderable area, stretching in a broad strip from the north from the Nerchinsk plant to the Otpor station of the Trans-Baikal Railway to the south. This area, territorially, is included in the Nerchinsk-Zavod, Aleksandro-Zavod, Byrkinsk and Borzinsk Rayons of the Eastern Siberia Kray. The largest deposits of the group are the Abagaytuy and the Solonech, of which the first is in operation.

Solonech Deposit¹

(¹ Description of the deposit compiled by the author together with I. V. Luchitskiy.)

The deposit is located in the Gasimuro-Zavodskiy Rayon of the Eastern Siberian Kray, on the left side of the Solonech River 9 kilometers to the north from the Solontsa settlement, which is located on the road of the Sretensk-Nerchinsk plants and 270 kilometers to the south-east (by highway) from the city of Sretensk.

The first mention in the literature regarding the deposit was in 1834 (Mining Journal, Volume I, "Description of the Nerchinsk Plants"), and further, only in 1916 P. P. Pili-panko [39] points to the occurrence of fluorspar in the Solonech Ravine. In 1927, Voynovskiy-Kruger [13] briefly cites the information that the deposit is located in biotitic granites and is connected with a thick vein of quartz. For the first time, prospecting was begun by the Far Eastern Exposition under the direction of N. W. Lavrovich.

The region of the deposit is a typical mountain region

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with large mounds. Systems of mountain spurs are dissected by broad ravines of almost meridional direction with brooks and small rivers of a mountainous nature flowing through them. These are tributaries on the left bank of the Urov River, which is rather high in the summer and frozen during the winter to the bottom. The Urov River, which is located to the south of the deposit, flows through a swamped valley, forming numerous meanderings and bending around the ranges of ancient granites.

The Solonech Ravine has a north north-east direction with the width of the valley near the deposit of 0.3 kilometer, and downstream for nearly 3 kilometers. For the entire length it is swamped, has several springs, which do not freeze over during the winter and which form large layers of ice.

The rate at which the rivers flow through is dependent, thus, on the precipitation and the thawing of the perpetual frost. During the rainy period (August and the beginning of September) they are in a state to flood the valleys so much that the latter become hard to cross for pedestrians, not to mention some forms of transport. The deposit itself is inadequately supplied with water and only during the hot period (July - August) is the prospecting work flooded on account of the thawing of the frost. The perpetual frost is spread over the entire region of the deposit.

The geology of the neighborhood of the deposit was studied in 1896 -1898 by A. E. Gedroyts; in 1931 the locality to the west of the deposit was studied by M. V. Besova. Some-

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what earlier a geological map of the eastern part of the region was compiled by Prizant. In 1935, prospecting together with geological surveying was carried out by the Far Eastern Expedition of the IMS.

Adjoining the vast granite mountain range (Jurassic Age), which encloses the fluorspar deposit from the west is the region of development of ancient Paleozoic (Cambrian) metamorphic rocks, Upper Paleozoic and Jurassic sedimentary formations, which intrude with young granites. But here, also, porphyrites in the form of dikes and, thus, of deposits, are widespread. The porphyrites pertain to Jurassic times.

More to the east of the deposit is located the region of development of the youngest effusive rocks (basalts, dolerites, liparites), which are deposited on the rocks of the Turga strata ($J_3 + Cr_1$). On the edge of this region, particularly along the eastern boundary of the Jurassic granite range, ancient (Cambrian) metamorphic rocks again crop out, cataclastic granite-gneiss and porphyrites, similar to those in the western part of the region. To the south the Jurassic granite range is separated from the Paleozoic granite-gneisses by the Urov River.

Paleozoic (Pz). The most ancient rocks of the region are represented by the various metamorphic rocks - hornstones, quartzites and crystalline limestones. In the middle of this stratum it seems possible to distinguish three independent stratigraphic horizons, the relationships between which are ob-

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served near the new settlement of Polovina (Bambuya Ravine).

The lower stratum (Pz₁) consists of biotitic, double-micaceous and biotite-amphibolic paragneisses. A subordinate role is played by the development, chiefly in the western part, of the biotitic, biotite-amphibolic and biotite-chloritic hornstones. The Quartzites and crystalline limestones which are present do not profit by widespread diffusion and form insignificant lenticular layers.

The middle stratum (Pz₂) is built up by feldspar and sericitic quartzites, frequently by sheared formations. The layers of crystalline slates, identical to the slates of the lower stratum, are subordinate to it. To the west of the deposit (Arkin Range) quartzitic-muscovite slates are diffused.

The upper stratum (Pz₃) is represented by crystalline limestones; generally the trend of all three strata of the Paleozoic is north-west with variations to the east in the north-east.

Judging by the data obtained by M. V. Besova, during a study of similar limestones in the Shira Ravine, where fauna of the Cambrian period is found, it seems possible to refer the upper stratum to this age.

Carbon (C?). In the Misturna Ravine a stratum of graywacke sandstones is developed, interstratified with greenish-yellow sericitized slates. In the slates are found

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(in 1935) rather numerous impressions of bryozoa: Fenestella (4 - 5 varieties, nearer indeterminates), Trepostomato (never indeterminate).

The stratum, undoubtedly, is of Upper Paleozoic age. The general trend of the rocks is close to north-east 80 degrees.

Jurassic ($J_1 - 2$). To the west of the deposit, along the road and in the ravines of Ugol' and Luchiy, are spread graywacke sandstones, interstratified with black clay slates. The trend of the stratum is north-east. The presence of Czekanowskia setacea Heer, determined by V. N. Prinadaya in 1936, and the lithological nature of the stratum, similar to the lower and middle Jurassic, prevalent near the Gasi-murskiy plant, permits the determination of the specified age.

Turga horizon ($J_3 + Cr_1$). To the east of the deposit are developed whitish sandstones and clay slates, similar in external form to the rocks which prevail near the mouth of the Byrka River and along the Turga River (Turga group of deposits). To this age is referred also the conglomerates along the banks of the Urov River. In the conglomerates, a boulder consists of limestones, granites, graywacke sandstones and hornblende porphyrites. The cement in the graywacke standstone is medium-grained. The Turga horizon is exceptionally weakly dislocated.

Rocks of dikes and deposits. These rocks profit by

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widespread dispersal in the region and are different in age. The most ancient of them - the porphyrites - are combined by Besova under the name of "effusive stratum" and are referred, in comparison to other regions of Eastern Trans-Baikalia, to the Upper Jurassic (J_3^2); to the east of the deposit, the porphyrites which are widespread there, are connected with this stratum and underlie the Turga stratum ($J_3 + Cr_1$).

The porphyrites cover a large area and are deposited partly in the form of dikes, partly in the form of deposits not only among $J_1 - 2$, but in places (bank of the B. Zerentuy) the hornblende porphyrites are located also among the quartzites (Pz). To the north of the deposit they occur among the Jurassic granites. Among the porphyrites, developed near the deposit, are distinguished: pyroxenic, hornblende and aphanitic porphyrites.

On the rocks of the Turga stratum, and partially also even on the porphyrites, occur deposits of basalts and basaltic almond rocks. Near the settlement of Gandybaya, at the point of contact of the basalts with the Turga stratum, a dike of dolerites, stretching in a north north-east direction.

The basalts of black or violet colors with intersertal hyalopilitic or vitrophyric structure consist of fine "leyst" of quite brilliant labradorite, granular augite and brown amorphous base. Relatively infrequently there are phenocrysts of augite and olivine in them.

The dolerites are medium-grained and consist of a

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"leyst" of labradorite No 57 - 65, augite, micro-pegmatite, quartz and brown amorphous base, which fills the intervals between with "leysts" of plagioclase, labradorite and small grains of augite. The structure is typical for the dolerites.

Near the settlement of Duchara a deposit of liparites lies on the basalts.

In a number of places, the liparites also occur in the form of dikes. Phenocrysts of liparites are formed by quartz, sanidine, biotite, rarely by andesine. The basic mass is felsitic, perthitic or spherulitic; in the dikes it is also micro-granitic. The age of the basalts, dolerites and liparites is youthful and pertains to the Cretaceous-Tertiary periods.

The intrusive rocks are represented chiefly by biotitic, biotite-amphibolic granites, granodiorites and quartzitic diorites, which form a number of huge blocks. The granites break through the stratum of Paleozoic metamorphic rocks, transforming the limestones into granitic-pyroxenic rocks and "in"yetsiruyut" the crystalline slates parallelly of the cleavage. They break through the stratum also of carbon (C?) and Jurassic ($J_1 - 2$) sedimentation, transforming the sandstones at the contacts, and the quartzitic and quartz-biotitic hornstones.

The ancient intrusions, represented by granite-gneisses and cataclastic granites (hornblendes and biotites), are widespread in the south of the region and pertain to the Upper Paleozoic.

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The geological history of the region appears to be as follows: Lying at the basis, the Paleozoic formations, which pertain to the Cambrian, were exposed, apparently, to Caledonian folding, in connection with which also occurred the intrusion of ancient granites. The presence of the following, variscite, folding is confirmed by the folding of the sedimentation. Intrusions of the variscite cycle in the described region is not established. The subsequent tectonic processes are "kimmeriy" folding of the first phase, adjoining to sedimentations $J_1 - 2$ north-east direction. With this phase is connected the intrusions of granites and effusion of porphyrites. The upper limit of age of this volcanic action is determined by the Turga stratum ($J_3 - Cr_1$) which leans on the porphyrites. The second phase of "kimmeriy" folding is weakly expressed; it only insignificantly dislocated the Turga Stratum and is connected with the effusions of basalts, dolerites and liparites (Cretaceous-Tertiary Period).

With regard to tectonics, the region is divided into two parts - western and eastern. The western part, by means of Paleozoic orogenic processes was gathered into a large anticline of north-west trend, and subsequently this rigid system reacted to the first "kimmeriy" phase of folding in the form of the creation of folds of a block nature, in places already of north-east trend (which is especially clearly expressed to the east, beyond the limits of the described region). This was connected with the formation of numerous disjunctive dislocations, which brought into reciprocal contact three different age complexes.

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1. The complex of Paleozoic rocks, dislocated in a large fold with a north-east and in places north-east trend with a dip of 50 - 70 degrees on both sides.
2. The complex of carbons (C?), which has a latitudinal trend and was dislocated into folds with angles of 40 - 50 degrees on both sides.
3. The Jurassic stratum with a general north-east trend, in places changing to the north-west.

The eastern part represents, apparently, a depression in this complexly dislocated base and is a region of comparatively mild stratification. The angles of dip here do not exceed 5 - 10 degrees. At the extremity of this region complexly dislocated ancient rocks again crop out.

Geology of the deposit. The age of the fluorspar deposit, genetically connected with the young intrusions of granites, is determined positively as Jurassic. Biotitic-hornblende granites, forming blocks, in external form are gray, porphyritic, from coarse-grained to average-grained and consist of quartz, oligoclase No 18 - 22, orthoclase, biotite and hornblende. The accessory rocks are apatite, zircon, titanite, ore mineral. The secondary rocks are sericite, chlorite, epidote and calcite. The structure is porphyritic, hypidiomorphic-granular. In the marginal zone of the range, on contact with the limestones, to the north of the deposit and on contact with the crystalline slates to the south, a quite gradual transition from granite through

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granodiorites to quartzitic diorites is observed.

The biotitic granites or granite-aplites in the vicinity of the deposit form rather numerous veins among the biotitic-hornblende granites of principally latitudinal trend.

The veinstones are represented by spessarites, aplites, pegmatite-aplites and, relatively rarely, veins of quartz. The latter are coordinated to the fluorspar vein. Prospecting trenches No 1, 8 and 15 on the side of the suspended side of the vein of fluorspar revealed metamorphized porphyrites. But they also occur in the northern part of the deposit, forming veins of north-east trend.

According to all indications the fluorspar vein itself is connected with the acid magma of Jurassic Age, precisely with the last cleavage of this magma in the magmatic basin above the already solidified and below the preserved liquid phase.

The fluorspar is found in the eastern (left) steep slope of the Solonech Ravine. The relative geodetic altitude of the deposit above the ravine is nearly 300 meters, with the length of the slope of the ravine up to the eastern end of the vein about 2 kilometers.

The deposit represents a typical complex vein with dense branches and numerous lateral veinlets, and in essence for almost its entire length is expressed by several approximately parallel veins, which are separated by barren rock. The vein

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zone is coordinated to the wide zone of tectonic shattering among the young Jurassic granites.

In general direction of the ore body, it approximates to the latitudinal; in details the trend of the vein is variable. In the western part, with the limits of trenches No 3 - 14, it has a direction south-east 110 degrees, further in the interval of trenches No 3 - 22 changes to the north-east (in the change of the trend to the north-east, within the trench No 3 the latitudinal trend is observed), that is, the trend of the vein corresponds completely with the primary fracturing of the enclosing vein of hornblende-biotitic granites, namely, north-east 48 degrees and south-west 115 degrees. Within the limits of trenches No 3 and 2 the northern branch of the vein passes through with a trend north-east 20 degrees and a thickness of 0.2 to 2.4 meters. The northern branch in form repeats in miniature the main part of the vein, swelling as does the former in its central part. The dip of the vein is north with fluctuations of the angle from 60 degrees and up to vertical. The thickness of the fluorspar vein zone varies within great limits: from 0.2 to 23.8 meters. Below in Table 10 the thickness is cited according to individual prospectings.

Along the trend the vein is traced by prospecting for a distance of about 700 meters. In the east, within the limits of trench No 22, the fluorspar is displaced by quartz, but to the west (trenches No 28 and 29) the tapering of the vein is not established. On the right side of the Solonech River, opposite the described vein, fragments of fluorspar have been found

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with quartz, and, it is possible, here that there is a continuation of the vein zone of the Solonech deposit.

Table 10

No of Trench	Thickness in Meters	No of Trench	Thickness in Meters
	Main Vein	2	3.6
14	2.4	6	2.8
12	1.7	22	1.0
10	10.2	Northern Branch	
7	10.4		
3	23.8	11	0.4
1	12.8	8	2.4
4	2.0	15	0.7
5	0.75	19	0.2

On the dip the deposit has been prospected by means of three prospecting pits: two in the central part of the vein at a depth up to 20 meters and one at a depth of 5 meters (near trench No 14). By means of bore holes, the fluorspar is cut up to a depth of nearly 50 meters on the vertical. Changes of thickness with the depth are not observed. The extent of the vein in depth is established at a maximum of about 95 meters, according to the hysometric marks of the outcroppings.

In composition the vein body is almost purely

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quartzitic-fluorspar; these components comprise up to 99 per cent of the vein mass. Of the other primary minerals, adular is present in an insignificant amount. Besides this, inclusions of fragments of secondary rocks and vein clay, filling the fractures, are present. The structure of the vein is principally breccia. The sharpest brecciated character is expressed in the wall parts of the vein, especially its under side, the vein preserved its totality, but in it there exist numerous interwoven fractures, which also give it a brecciated character.

It seems possible to distinguish two parts in the vein: an essentially quartzitic part and an essentially fluorspar part with more or less gradual transitions from one to the other. The first, as has already been pointed out, is located, basically, in the under side of the complex vein, and to a lesser degree in the suspended side.

On contact with the lateral rocks, it consists of pure quartz with numerous inclusions of fragments of it, and in size approaching to the fluorspar part, among the quartz fragments of fluorspar appear, the amount of which further increases and the quartzitic zone rather gradually passes over the fluorspar.

The proportions of the essentially quartzitic part with the essentially fluorspar part in the various parts of the vein are different. At the same time, the thickness of the first is more constant than the second. The size of the

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fragments of fluorspar is extremely various. Usually the fluorspar is broken into large fragments, which are separated from one another also by comparatively large veinlets of quartz. Inside these large fragments, it is broken into fine fragments about the size of micro-breccia. The transition of the vein into secondary rocks owing to the presence of large fragments of secondary rock and numerous indistinct apophyses sometimes is difficult to determine. But in places the contact, especially of separate veinlets with enclosing granites, on the other hand, is expressed clearly, inasmuch as the processes of conversion are almost absent.

Inclusions of fragments of secondary rocks are concentrated chiefly in the lateral parts of the vein and have a variegated form and size. Large fragments, reaching 1 meter and more in diameter, usually possess an angular, elongated form and are stretched out along the vein. Small fragments of 1 - 2 centimeters most often of all are round, and in places are present in large quantity, although, as a rule, in the central part of the vein they are almost absent. The whole vein stratum is broken up into fragments according to directions: north-east 37 degrees $\angle$ 90 degrees, south-east 141 degrees $\angle$ 75 degrees and north-east 336 degrees $\angle$ 90 degrees (average of measurements carried out).

The enclosing rocks of the vein zone on contacts with the vein bear traces of profound changes, incomparably more sharply and broadly developed than the other deposits of Eastern Trans-Baikalia. The strip of transformed rocks reaches

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a width of 100- 120 meters and macroscopically is expressed in the purification of the rocks. In character these changes represent hydrothermal metasomatism, in which, during a microscopic study, are distinguished several successive stages. In the granites primarily occurs a partial sericitization of the plagioclases and a partial chloritization and epidotization of the dark colored minerals. Nearer to the vein, but sometimes still 10- 12 meters from it, the plagioclase is almost entirely sericitized - and precisely, the colored minerals pass over into muscovite and sericite. The potash feldspar in this stage are preserved still almost fresh. The following and last stage is expressed in the complete disappearance from the granites of the feldspars and dark-colored minerals. The former are replaced by fine-grained aggregates of secondary quartz and sericite; biotite is completely replaced by muscovite. In the final product an increased content of apatite in the form of thin discs and prisms is noticeable. Besides the enumerated phenomena, the rocks in contact were insignificantly pyritized. Kaolinization does not play any role. Fluoritization is expressed in the filling of the fractures of disintegration in the rocks. Sometimes the fluorspar produces impregnations in the granite, penetrating the individual, fine round grains in the secondary quartzitic-sericitic aggregate.

The reserve of fluorspar on January 1, 1933, was expressed by the following figures (according to categories):
 A₂, 57 thousand tons, B, 138 thousand tons, C₁, 172 thousand tons, C₂, 286 thousand tons.

In the calculation of the reserves the removal from

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the fluorspar of barren rock, nearly 30 per cent on the average, was taken into consideration.

Below is shown, in Table 11, the contents of CaF_2 and SiO_2 in the individual workings.

Table 11

No of Trench	CaF_2 in percent		SiO_2 in percent	
	From	To	From	To
2	88.71	92.99	7.03	9.07
1	59.01	86.06	11.66	36.36
4	-	79.71	-	17.56
7	70.11	89.49	8.22	27.43
6	43.09	88.01	9.45	50.88
8	90.25	91.54	6.50	6.91
3	73.15	91.40	6.97	24.39
Pit 1	11.88	92.18	5.43	83.47
Pit 2	80.66	90.60	8.01	16.57

In the samplings of prospecting operations, veins of barren rock, beginning from a thickness of 0.1 meter and higher, were not included in the experiment.

As is seen from the analyses brought out, the quality of the fluorspar, is exceptionally various, but, using only hand sorting even, it seems possible to obtain all its quality.

The reserve in category A_2 can be divided into the following groups according to contents of CaF_2 (Table 12).

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Table 12

Characteristic of Variety with Con- tent of CaF_2 in %	Reserve of Variety in % to General Figure A_2	Reserve according to Variety in Thousands of Tons
80 and above	41	23
70 - 80	33	18.8
50 - 70	26	14.8

At the present time (1936) prospecting is being performed for the purpose of transferring the reserves of categories B and C respectively to A_2 and B.

The greatest disadvantage of the deposit is its remoteness from the railway (nearly 270 kilometers by road). Besides the remoteness, another disadvantage is the inaccessibility of the road for auto-transport traffic at all times of the year.

A possible alternative way of transporting the fluorspar is by road (65 kilometers) to the Nerchinsk plant, and then by the Argun and Amur rivers to the Albazino station on the Amur Railway. The deposit is well provided on the spot with wood for building and for supports.

In any case the deposit requires a thought-out, economical analysis for the purpose of determining the advantageousness of operating it.

The Purinsk deposit is located on the eastern side of the

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village of Pura, on a number of mounds, which stretch out approximately in a latitudinal direction and which are dissected by shallow ravines with a large quantity of coarse fragments of vein quartz. The first spathic mound is situated in the south, and further toward the north is the second, third, fourth and fifth.

The arc of the deposit is built up in its southern part by metamorphic slates, sandstones and crystalline limestones (Paleozoic). The whole stratum is broken through by granites, to which also is coordinated the majority of the veins of fluorspar.

The first spathic mound is built up by metamorphic slates and sandstones; the vein of fluorspar cuts through it in a latitudinal direction with a thickness up to 0.10 - 0.15 meter. The fluorspar is of finely-columnar structure, brick-red color (a color rarely encountered among fluorite), slightly similar to certain varieties of fluorspar of the Tamanga l deposit. The vein, in the casings, is accompanied by considerable veinlets of quartz.

The remaining four mounds are built up by granites and all are fluorspar-bearing. The most reliable portion in amount of fluorspar- is the Fifth spathic mound, where ten years ago already local extraction operations were being carried on by means of small open-pit mines along the trend of the veins. The fluorspar is yellowish and light-rose - very rarely dark-violet, and almost black in several varieties; in structure it approximates the Abagaytuy, but with a considerable content of silicic acid in the form of chalcedony and more often of vein quartz. The trend of the majority of the veins is north-east 25 degrees, with an abrupt dip

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to the east. On the fifth spathic mound is established the presence of five veins, which extend, in all probability, parallel to one another. All veins are considerable silicified; the silicification increases with depth.

Judging by old dumps, which were created at the time of extraction, the beneficiation of the fluorspar was performed immediately on the spot by means of crushing it and then removing the quartz by manual sorting.

The deposit is located in a place where transport conditions are difficult, and with insignificant reserves scarcely merits the attention of industry.

The Man'kov deposit is located 6 kilometers to the south of the village of that same name, near the road leading to the Al-gachin mine.

Basically, the region of the deposit is built up by Jurassic conglomerates, which are composed of excellent rolled pebbles of various sizes, cemented by small-grained sandstones. In insignificant quantity, there are outcroppings of greisenized granites, chiefly in the vicinity of the vein of fluorspar or on its casings.

The vein of fluorspar revealed by prospecting trenches extends, with breaks, nearly 1.5 kilometers and has in the eastern part a trend north-east 40 -45 degrees / 80 - 85 degrees north-west; but to the west the trend changes to the latitudinal with a dip of 45 degrees to the south. The thickness of the vein fluctuates within the limits of 0.2 to 0.7 meter. The fluorspar is compact-crystalline, violet and green, with a large content of

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quartz. In a north-east direction the fluorspar passes over into a quartzitic vein with a thickness of up to 0.5 meter. To the west the content of quartz also increases. The total quantity of fluorite in this part of the vein scarcely reaches above 30 percent. The deposit has no commercial importance.

The Konduy deposit. The outcroppings of fluorspar discovered by Yu I. Freyval'd are coordinated to the north-western right slope of the Sukhaya Uburbulak Ravine. The latter is situated 7 - 8 kilometers to the south-east of the village of Konduy and 5 - 6 kilometers to the north of the village of Naryn. The relief of the region of the deposit is typically mound-like, highly eroded. The northern part is mountainous, but the southern part is represented by the valley of the Urulyunguy River, which reaches a width of 15- 20 kilometers. The absolute height of the highest point of the positive relief is nearly 1,000 meters, and of the valley 600 - 700 meters.

The area of the deposit is built up chiefly by granites, which intrude into the stratum of the metamorphic slates. Remains of the latter are represented by blocks of amphibolites, biotitic gneisses and from time to time limestones. These rocks were preserved by the main mass at the edge of the intrusion in the form of more or less large blocks. The pure granite is slightly micaceous, biotitic or yellow color, fine-grained.

The gneisses, encircling the granite block from the south and south-east sides, have a trend: latitudinal 35 - 45 degrees north and south and north-east 30 degrees $\angle$ 20 - 40 degrees south-east. The composition of them fluctuates depend-

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ing on the amount of "in"yetsiruyushchiy" material of primary composition and degree of assimilation. The most widespread of them are the hornblendes and hornblende-biotitics.

A characteristic peculiarity of the block is the coordination of the products of the pneumatolytic and hydrothermal phases to its south-eastern part and its complete absence in the north-west. This marked regularity is connected with the nature of stratification of both sides, of which the north-western is as though the under side, and the south-eastern the suspended side.

The veinstones are represented by a great quantity of quartzitic veins and in some places by small veins of aplite. Pegmatites are not encountered at all. Among the quartzitic veins, two types are sharply distinguished, different in form and time of formation. The first type is encountered rarely and chiefly on the right side of the Konduy River. It is represented by dense gray quartz, sometimes with a rose shading, dense porcelain-like with numerous cavities, filled with prismatic crystals of rock crystal and sinter forms of chalcedony. With this type the fluorite is connected, forming in it pocket-like accumulations of individual crystals, veins and veinlets. The second type, undoubtedly, is later; in it are differentiated three genetical factors: the formation of milk-white quartz, the lixiviation of it with the formation of cavities, with the further filling up of them by fluorite; later are formed prismatic and sinter forms of quartz and chalcedony in the form of coatings on the surface of the fluorite and the cracking of it.

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The fluorspar, as indicated, is clearly connected with more or less large quartzitic veins, including its veinlets, veins and accumulations of separate crystals.

Outcroppings of quartzitic-fluorspar veins is established at four points. The first represents a strongly eroded quartzitic vein, which stretches along the right side of the ravine near its water-collecting depression, with a trend north-east 5 - 10 degrees. The portion of the vein left intact by the erosion is traced for a distance of 90 meters, with a thickness of 0.5 to 1.5 - 2 meters. The fluorspar forms in it a network of veinlets and pockets from 1 to 10 centimeters in diameter. The content of fluorspar in the ore body does not exceed 15 - 20 percent.

The second point is located on the southern side of the pass and represents a quartzitic vein with pockets of violet fluorspar. It is traced for a distance of nearly 110 meters, with a trend north-west 350 degrees and a thickness of 1.8 meters. In places of greatest accumulation of fluorspar, its veinlets do not exceed 12 centimeters and are located very rarely.

The third outcropping is represented by fluorspar, in large part quartzitized to the highest degree. The trend of the vein is north-west 328 degrees $\angle$ 50 degrees south-west. The prospecting trench which passes through has established the extent of the vein up to 180 meters with an average thickness of 0.40 meters. On the average the content of fluorspar in the vein reaches 40 - 50 per cent. The fluorspar is coarsely-crystalline, of violet color of all shades and green; colorless varieties are rarely encountered. The crystals encountered in the form of

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cubes or octohedrons are surrounded by a quartzitic coating; in places the fluorspar in the vein among the quartz forms unbroken accumulations.

Individual fragment of fluorspar showed the following content: CaF_2 , 96.36 per cent, SiO_2 , 3.02 per cent.

The final point (the fourth) is located in the pass between the Sakhetuy and Sukhaya Uburbulak ravines. Here is established the presence of three large quartz veins with a thickness of from 5 to 20 meters and with a trend north-east 5 degrees and north-west 320 degrees. Fluorspar is encountered in them in individual pockets, frequently of great size, up to 0.5 meter in diameter, but are located so rarely that it is not worth speaking of their commercial importance. The crystals are well-formed in cubical form, with individual ones from 0.5 to 10 centimeters in diameter.

In conclusion it should be noted that in spite of the comparative nearness of the deposit to the railway (80 kilometers), it does not have commercial importance in reserves.

Urulyunguy deposit was discovered in 1932 and is located 5 - 6 kilometers to the south-east of the village of Ust'kirkir of the Byrkinskiy Rayon and 130 kilometers to the east of the Borzaya station and Dauriya station of the Trans-Baikal Railway. It is located on the right bank of the Urulyunguy River, near the south of the Idonga Ravine, on its right side. The deposit is coordinated to the small mound, which rises above the valley to a height of 50 meters, the dome-shaped summit of which is stretched out almost in a meridional direction, with slanting slopes on all sides. The length of the elevated part of the mound (along the summit) is nearly 250 meters.

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The Urulyunguy River in the region of the deposit flows through in the direction of east north-east; below the village of Ust'Tasurkaya it turns to the east and flows into the Argun' River near the village of Novotsurukhaytuy. Its valley is wide (6 - 10 kilometers), almost flat. The channel of the present day river is nearly 10 meters wide, up to 1 - 1.5 meters deep. During the winter the river does not freeze over, and the local population uses it as a source of drinking water. From the Urulyunguy deposit to the river the shortest distance is 5 kilometers.

As a consequence of the strong smoothing of the relief by erosion, there is very little natural outcropping in the region of the deposit.

Judging by the few outcroppings and artificial developments, the region of the deposit is built up by coarse-grained granites, consisting of rose-colored feldspar and gray quartz, with the former predominating. Biotite is encountered, but extremely seldom. Granite in typical form is found by prospecting to the west and north of the fluorspar vein. Regarding the distribution of those same granites to the east and south of the vein, it is possible to judge this by the presence of a great quantity of fine alluvial deposit of rose-colored feldspar on the surface of the ground. In all workings (with maximum depth of 5.5 meters) the granite is strongly weathered and scattered into separate parts. In the vein zone the granite strongly is changed - the feldspar completely passed over into a greenish-white chloritic-clayey mass, which also connects the remaining grains of quartz. A characteristic feature of the vein

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zone is also the abundance of quartz, which forms veinlets, lenticular formations, and in places impregnates and cements the porous mass of crumbling granite.

The width of the strip of transformed granite is not established (its eastern boundary has not been discovered), but, judging by the data on the western side of the vein, the change referred to is limited by a narrow strip (up to 3 meters), which directly adjoins the fluorspar vein. Upon removal from the vein, the granite gradually passes over into a normal type. These data permit us to consider the disintegration of the feldspar of the granite as the result of contact action of the vein body.

In the middle of the granite occurs, also, veins of white fine-grained quartz, enclosing small formations of fluorspar.

The vein of fluorspar occurs among the described granites and stretches along the summit of the mound, emerging into the surface in its central part. Along the trend it is established by trenches for a distance of 170 - 180 meters.

The path of the trend of the vein in this stretch is bent in an arch with the convex side on the west. At the southern end it has a trend north-west 340 degrees, in the middle part gradually passes over to the meridional and further to the north bends to the east by north-east 10 degrees. The dip of the vein is to the west at an angle of 80 degrees, sometimes more. According to the data of the deepest working, the suspended side of the vein dips on more of a slant in comparison with the under side, on account of which the thickness of the vein increases with depth.

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The vein consists of fluorspar and quartz. The structure of the main vein is compact-crystalline; the color of the fluorspar, basically, is green. A tint of other colors, most often of all in violet, is present with separate spots, without any uniformity. Only at the southern end is the fluorspar of intensive violet color with small green sections. The vein of fluorspar is pierced by a network of veinlets and lines of quartz.

It is characteristic, that in the immediate vicinity of the surface there is comparatively little quartz in the vein. At the same time, with considerable depth the quantity of quartz noticeably increases, chiefly on account of the increase in thickness of the parallel veinlets and lines. On the other hand, the "quartzability" increases from the center toward the ends of the vein, especially noticeable for the northern end.

The vein of fluorspar sometime is separated from the surrounding granite by a veinlet of quartz; the transformed granite near the contact always is impregnated and cemented by silicic acid. Contacts of the fluorspar both with the granite and also with the quartz are sharp, uniform, often flat. In the direction contact of spar and granite, a fine brown clay fringe usually passes through along the contact.

The thickness of the vein is greatest in the middle part of it and reaches 1 - 1.2 meters. To the south and north the thickness decreases to 0.40 - 0.50 meter.

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The most southern trench revealed a vein of white quartz with inclusions of lines of fluorspar about 3 meters thick.

The reserve of the deposit in category B + C reaches 5.5 thousand tons.

The content of CaF_2 and SiO_2 in the ore fluctuates for the first from 76.11 to 87.82 percent and for the second from 8.75 to 18.82 percent.

The Ust'-Tukulanda deposit is approximately 1.5 kilometers to the south-west of the Idong deposit, on the left side of the Tukulanda Ravine, on a small promontory which juts out into the valley of the Urulyunguy River, where over a considerable area is distributed a fine alluvial deposit of pure fluorspar.

In addition, there are separate, round, small lumps, which consist of breccia of secondary rocks, cemented by fluorspar and quartz. These lumps occur without any apparent regularity among the porphyrites. The trend of the discovered veinlet is north-west 245 degrees, the dip is nearly vertical with a slope to the east.

The "Zeren" deposit is between the villages of Ust' Kirkir and Ust' Tasurkaya. Here, in the valley of the Urulyunguy River, from its left side, the Zeren Ravine comes out.

The presence of three veins has been established, which stretch in the direction of north-east - south-west; along the trend they are traced up to 100 - 130 meters. The great-

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est thickness of the vein is up to 0.3 - 0.4 meter, usually less. The veins occur among strongly changed and silicified granites. The veins are filled with fluorspar, with a large quantity of breccia of the surrounding rocks, highly quartzified. These veins do not have commercial value.

The Kharakazagorsk deposit is coordinated to the slope of the mound of that same name, approximately 11 kilometers to the north-east of the Abagaytuy mine. The nearest populated points are the villages of Maryn, 20 kilometers away, and Bogoga, 30 kilometers to the east of the mine. With regard to orography, this region in distinction from the comparatively equal area of the Abagaytuy deposit is formed by levelled down mounds. The predominant rocks at the deposit are the granites, bursting open a stratum of Jurassic (?) metamorphic slates and sandstones. In the granite, sometimes the quartz, sometimes the fluorspar form large deposits, and the rock receives a porphyritic structure. Biotite and pyroxene are present of the dark-colored minerals; the latter, together with feldspar, creates in places a streaky formation of dark-green color. Near the veins of fluorspar and on contact with them, the granites are kaolinized and transformed into gravel. The metamorphic rocks are the chloritic slates and arkose sandstones, adjoining the deposit from the west in a meridional direction. They are pressed between two granite blocks, exposed to strong silicification and are divided by the fracturings into fragments in the directions: north-east 85 degrees / 45 degrees south and north-west 325 degrees / 45 degrees north.

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A similar fracturing appears also among the granites, whereupon all quartz veins are coordinated to the fracture with a direction north-west 295 -325 degrees, and the veins of fluorspar to the second system. The fact of the coordination of the veins of fluorite to the one fracture and the quartz to the other and the breaking away of one of the veins of quartz by one vein of fluorite is explained by the difference in the times of the formation; the fluorspar was formed later. The observations produced afford the possibility of assuming the existence in the creation of the ore bodies of a minimum of three phases, resulting in the successive formation first of quartz, then of fluorspar. The process of formation of the veins was concluded by the formation of silicic acid; the central part of the vein zone is filled by quartz.

The veins of fluorspar which were revealed by prospecting trenches showed a thickness within the range of 0.12 to 0.20 meter. The fluorite has a compact-crystalline structure with intensive colorations of green or violet colors. The deposit has no commercial importance.

The Urtuy deposit is located to the east of the preceding one, approximately 10 kilometers to the south of the Botogotuy Mound, on the slope of the Belokopytnaya Ravine. The outcrop of fluorspar onto the surface is represented by individual fragments. The trenches laid near these fragments encountered a thick stratum of detritus, composed chiefly of granite gravel and fragments of green and rose-colored fluorspar. The vein occurs in the middle of porphyritic granite

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of the post-Jurassic Age. In the fragments of fluorspar it is traced for 30 meters with a trend north-east 20 - 25 degrees and is directed at a sharp angle toward the quartz veins. The region of the deposit serves for the organization of preliminary prospecting.

The Chirsk deposit is located 3.4 - 4 kilometers to the north-west of Abagaytuy, on the left side of the Dayk Ravine, in the spurs of the Chirsk Mountains. The area of the deposit is bound on the north by the Balaguy Mound and Chir Mound, on the west by Ayarak and on the east by Typkucha.

The veins of fluorspar, which occur among the granites, have been known since 1926, when exploitational operations were begun by Engineer Ziks. In 1928, prospecting work was performed by the Institute of Applied Mineralogy (now the IMS).

Outcroppings of veins on the surface are reflected by weak strips, composed of small fragments of fluorspar and milk-white quartz.

At the deposit two veins have been established, converging in the north, where their great "quartzability" is observed. The eastern vein, with an average trend north-west 357 degrees / 70 degrees west, is revealed for a distance of nearly 500 meters; the fluorspar is distinguished by its purity and rather easily by the formation of an intrusion of barren rock. In the upper part of the vein it is strongly shattered and broken up into small, well-expressed cubes and octahedrons, and yield a greater quantity of fluoritic fines with abundant adhesive, sticky, ochreous clay.

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Further below the surface the fluorite is more solid and has a compact-crystalline structure.

Prospecting of the western vein up to the end has not been finished (it has been traced for a distance of nearly 200 meters, and with a thickness of nearly 1 meter it yields pure, dense fluorspar with an insignificant quantity of fines). In a calculation of the average thickness of the eastern vein at 0.5 meter and the western at 1 meter, and occurring at a depth of up to 5 meters, the reserves in category C_1 are expressed as 7 thousand tons.

The continuation of the vein at a great depth, with the preservation of the referred-to thickness, judging by the prospecting pit of Engineer Ziks, is doubtful. The organization of prospecting operations is completely possible, the more so, since the deposit is only 4 kilometers farther from the railway than is Abagaytuy.

The Abagaytuy deposit. The extraction of fluorspar was first begun in 1914-1916, when nearly 1,000 tons were obtained by opencut mining. From 1918 to 1925, the mine was not worked, and only since 1925 has prospecting work been begun by the Institute of Applied Mineralogy (now the IMS) in passing with operation. Further, the mine successively was managed by the Mining-Chemical Trust, the All-Union Association "Mineralrud", and now is part of the trust "Soyuzplavik".

It seems possible to establish the quantity of fluor-

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spar extracted more or less exactly only since 1925- 1926, and it is expressed in yearly figures, given in Table 13.

Table 13

Years	Sorted out Fluorspar in Tons
1925 -1926	2,433
1926 -1927	840
1927 -1928	3,061
1928 -1929	3,112
1929 -1930	7,026
1931	7,829
1932	3,200
1933	4,133
Total	31,634

Considering the considerable amount of fluorspar fines, which are formed during extraction and left on the dump or separate piles, and which are found even up to the present at the mine in an amount of nearly 10 thousand tons, with a content of CaF_2 of 40 to 60 per cent, it is necessary to suppose that during the entire time of the existence of operations, beginning in 1914 and ending in 1933, 45 - 50 thousand tons of fluorspar have been mined.

Prospecting work was begun in 1925; the first time the operations resulted in passing through trenches and pits;

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further, core drilling was performed for the purpose of augmenting the reserves in the dip of the vein. The three holes passed through did not attain the objective, inasmuch as they were drilled almost at an angle of 90 degrees, with an abrupt dip of the vein to the east, and sometimes also with a reserve dip to the west.

In 1931, the tested reserves almost entirely were worked out and raised the question regarding the conservation of the mine or regarding urgent carrying out of prospecting work. The drilling work begun in that same year by the expedition of the Institute of Mineral Raw Materials (the former Institute of Applied Mineralogy) proved the presence of fluorspar in the northern part of the deposit (the region of pit No 9), where later on shaft No 3 was put through, which is still working at the present time (work has not been carried on in shafts No 1 and 2 since 1932). In 1933 - 1934, deep prospecting was carried out in the main vein, where the presence of fluorite has been established down to a depth of 130.5 meters on the vertical. This increase, or, more accurately, restoration of reserves in the deposit up to the figure, increasing the quantity of extracted fluorspar for the whole time of existence of the mine, is of considerable industrial interest. Pending construction in the Union of a concentration plant, the Abazaytuy mine is for the present almost the only one which can satisfy in one or another degree (with careful sorting of the fluorspar) the demand of the cryolite industry.

The granites and the various effusive rocks, the ande-

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sites, porphyrites, their tuffs and tuff-breccia, occupy the predominant role in degree of distribution. The sedimentary rocks crop out in the form of separate islands among the indicated volcanic rocks. In the vicinity of the mine they are represented by sandstones and siliceous slates. S. A. Muzylev refers the complex of effusive rocks, on the basis of similarity to other regions of Trans-Baikaliz to the Upper Jurassic formation.

Basically, the area of the deposit itself is built up by labradoritic porphyrites and their tuffs, referred by Muzylev to the Upper Jurassic. The granites, distributed in the northeast corner of the deposit, near shaft No 3, are younger in relation to the porphyrites and break through the latter. On contact they created a considerable quartzitizing of the porphyrites and numerous veins of quartz, passing over sometimes along the trend into fluorspars. In external form the granites possess a light-rose color, porphyritic structure and are kaolinized by feldspar. The porphyritic formations are quartz. Non-ferrous minerals are present in insignificant quantity. Under the microscope the granite consists of quartz, feldspar, microcline, orthoclase and plagioclase, chloritized biotite and sericite, and muscovite in very small quantity. Quartz is present in large quantity in the form of different sized crystals. Orthoclase is encountered in small quantity and in lesser degree is exposed to shattering. Plagioclase is represented by albite and albite-oligoclase, and is strongly sericitized.

The labradoritic porphyrites occupy almost all the area

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of the deposit and are enclosing rocks in relationship to the veins of fluorspar. In external form they are dark, rarely light gray, with various shadings from green to cherry-red, fine-grained, with porphyritic plates of feldspar. Large amygdules are often present.

The rock is divided into fragments by fracturing with the following directions: north-east 5 - 30 degrees $\angle$ 40 - 65 degrees southeast; north-east 285 - 300 degrees $\angle$ 55 - 60 degrees north-east.

Basic processes of change of the porphyrites took place in the direction of kaolinization, chloritization, silicification, pyritization and fluoritization. The latter is observed for the most part within the limits of the vein zone. Carbonization is encountered at the deposit everywhere.

Under the microscope the porphyrite possesses porphyritic and, more rarely, "afiroviy" structure. It is possible to establish two generations of minerals; the first in form is well-preserved labradorite and the second, a component of the main mass of rock, in form is plagioclase, small grains of augite, ilmenite and apatite.

Basalt, exposed to strong changes, is represented under the microscope by a large quantity of dirty-brownish and dark-gray, weakly acting on the polarized light, mass. In it is encountered the following components: vitreous base, plagioclases, monoclinic pyroxenes, ore inclusions and, rarely, apatite. In the vitreous base, only now and then can the presence of micro-

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lites of plagioclase be established. The plagioclases - labradorite of various acidity - are encountered in the form of comparatively large porphyritic formations and microlites. They are exposed to a great degree to sericitization, carbonization and chloritization. The ore inclusions more often are encountered in the form of shapeless, silicified spots and more rarely in the form of squares of titanite. Near the vein of fluorspar in the basalt, the finest crystals of pyrite appear. Apatite is encountered rarely.

The amygdules which are present in the basalt in the central part, are filled with quartz, after which sometimes follows chalcedony, further light-blue chlorite and then again a coating of chalcedony. The second variety of amygdule consists of chlorite, dissected by the ore border, and of the rim, built up by chalcedony.

The basalt tuffs of reddish and brownish colors occupy the northern and western part of the deposit. They sometimes possess cavities, which are filled by limonite, agate, chalcedony and quartz with a chloritic coating. Under the microscope the basic mass consists of rare, flat forms of crystals of plagioclase and of phenocrysts of ore mineral. During disintegration, a tuff from the deposit of the amygdule has a porous form, is kaolinized and limonitized and on the surfaces of erosion is deposited a crust of calcite.

The veins of fluorspar are connected with the fractures of the break by the total length of 1,200 - 1,300 meters, running

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through the basalts and partially among the granites. The veins, according to the nature of the conditions of occurrence, forms the mineralogical composition, can be divided into three groups, situated as follows: the first is in the region of contact of the basalt with the granites, the next in the northern part of the deposit, and the last in the southern part. The boundary of the last two regions passes through a latitudinal direction through pit No 7. In the southern region, within the limits of shafts No 1 and 2, there is only one vein with an established length of 550 - 600 meters and a trend north-east 15 - 30 degrees $\angle$ 75 - 80 degrees east. In several short portions the angle of dip of the vein changes to the vertical, sometimes assuming, too, a reverse, abrupt dip to the west.

In the region of contact of the granite with the porphyrite are found four short veins of fluorspar; their trend follows the basic line of contact, namely, north-east 75 degrees $\angle$ 85 degrees south-east. Several of them occur partially in the basalt, partially in the granite. The thickness of the vein is insignificant and fluctuates from 0.05 to 0.3 - 0.4 meter. The structure of the veins is ribbon-symmetrical, with a preponderance of fluorspar of violet and green colors, with inclusions of fragments of the enclosing rocks. In several individual zones of ore bodies, quartz displaces the fluorspar.

The northern region is characterized by the presence of an entire series of fractures of different sizes, but short, chiefly, in which subsequently veins are formed, for the most

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part connected with one another, branching out, mutually intersecting, but converging in a fan-shape in the north-west. The veins of this region are distinguished by comparatively small thickness of 0.1 to 0.5 meter are rarely up to 1 meter; their maximum length is 140-150 meters. A majority of the veins possess a north-west trend within the range of north-west 325 to 340 degrees $\angle$ 70 - 80 degrees east, but sometimes they deviate from north-east 15 - 55 degrees. The possibility of the presence in the region of short fault-dislocations of a step-like nature is not excluded.

Thus, the northern region is characterized by the intensive shattering of the porphyritic covering with the presence of a large amount of fractures of comparatively small extent and thickness.

1. The vein-like quartzitized zone, which is more ancient in comparison with the rest and which is a rose-gray rock, is a basalt, modified in the middle part of the vein, and a greenstone in the basic, less changed parts. In those cases when open cavities remain in this rock, they are filled in the walls by fluorspar; the central part by fine-grained quartz, which form lines and veinlets. These veins, more accurately, vein zones, usually consist of a number of parallel centers of silicification with an extinguishment on both sides, and they form as though in groups of convergent veins with a thickness of 0.1 - 0.2 meters and more rarely 1 - 2 meters. The trend of the zone is north-west 12 - 18 degrees, north-east 12 - 65

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degrees and latitudinal with angles of dip of 45 - 75 degrees. The quartzitized zone is intersected by the quartzitic-fluor-spar veins, whereupon the form, in these cases, is faulted and dislocated for a short distance.

2. The quartzitic-fluorspar veins have a north-west trend within the range of north-west 340 to north-west 345 -360 degrees north-west $\angle$ 70 - 8- degrees. The whole group forms, as it were, two clusters around the vein, exploited by shafts No 3, converging in the north-west. The thickness of the vein fluctuates from 0.6 to 1 meter, with bulges in certain points up to 2 - 3 meters. A typical section of the vein zone is as follows: the central part is represented by milk-white, compact or porous, fine-grained saccharoidal quartz, but toward the periphery is observed alternating thin bands of violet and green fluorite with quartz, with the former predominating. Further follows pure fluorspar of ribbon structure, and the casings are represented by silicified breccia of basalt. The constant presence of chalcedony is characteristic, although in the form of the finest veinlets between the fluorite and the porphyrite at their point of contact.

The veins on the trend rapidly swell and contract; at the same time, the bulges often occur on account of the enlargement of the central quartzitic part with the simultaneous enlargement in it a pocket-like formation of fluorspar with coarse-crystalline, compact structure. Among all of the veins of the northern region, the vein, which is being worked at the present time by shaft No 3 (formerly pit No 9), which has the names "Sakhalinskiy" and "Staratel'skiy" at the mine, located

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now to the north-west of pit No 7, merits attention. The former is distinguished by comparatively great thickness, its uniformity and pure composition. The average thickness in the part revealed by cleaning operations amounts to 1.25 meters. The trend of the vein is north-west 342 degrees 75 - 82 degrees east.

The transition from the northern region to the southern is characterized by the fact that the main vein, which stretches in a north-east direction, near pit No 7 is divided along the small fractures into a number of fine branches with directions differing from north-east 45 degrees to north-west 330 degrees, with the prevailing trend close to the meridional. Further, the vein gradually assumes a north-west trend, forming three basic branches; they are traced in all three horizons of shaft No 1 (northern drift).* [* Errata: Pages 64 and 65. The word basalt and derivatives regard with porphyrite.]

The characteristics brought out regarding the northern and southern regions are explained completely by the fact that the first directly adjoins the granite intrusion, and the porphyritic deposit here was exposed to its most intensive action, which is expressed in the creation of numerous fractures; but further toward the south a dying out of tectonic processes occurred, and in the presence has only one fracture. Their mineralogical composition is also an essential difference of the veins of the northern and southern areas. While the composition of the northern complex of veins is distinguished by an abundance of white saccharoidal quartz, in the main vein the corresponding quartz is encountered only in the northern

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part, but further to the south chalcedony predominates. On the other hand, in the region of shaft No 2, on all three horizons, barite and the products of its disintegration are present, and also kaolin admixed with fluorspar. The latter rock is usually of white or cream color, sometimes is silicified, and, in this case, has a porcelain-like fracture. A typical chemical analysis of the rock is as follows: CaF_2 , 53.64 per cent; SiO_2 , 15.16 per cent; Al_2O_3 , 18.17 per cent; traces of BaO or up to 5 - 6 per cent; and Fe_2O_3 , 0.08 per cent.

The main vein is distinguished by relatively constant thickness, but as a rule, resulting in the diminution of its average size with movement from south to north (Table 14).

Table 14

No of Shaft	Name of Drift	Average Thickness in Meters	Note
2	Southern	0.99	Thickness is
	Northern	0.60	indicated for
	Same	0.55	third horizon

In individual sections of the vein its form is irregular; it possesses bulges up to 1.75 - 2 meters and short sections of reduced width with the thickness of the fluorspar up to several centimeters. Often branches are observed with the formation of short apophyses. The cavities which are present

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in the center of the vein zone, which quickly expand and contract, are filled with kaolin, which is found admixed with fluorspar and sometimes with the products of the disintegration of barite. Frequently, this rock has the form of breccia owing to the fact that its cemented fragments (by silicic acid or fluorite) are scattered in the softer surroundings of this same rock.

There are inclusions of acute-angled fragments of fluorspar. In places crystals of barite are encountered with sizes up to 5 centimeters in diameter, covered by a fine crust of amber fluorspar. Most often, pseudomorphic forms are encountered in the barite in the form of a film of fluorite, which envelops the products of the lixiviation of barite of grayish-white color. In the deep horizons (hole No 6) the fluorspar has a foliated character, owing to the presence in it of numerous foliated clusters, filled with quartz, pyrolusite and calcite. From the central part of the vein body to the periphery occur formations of fluorspar of ribbon-like structure with coloration of individual strips in violet, green, cream and gray color or colorless. The color is listed in the order of its change from the periphery to the center. Sometimes individual strips are dissected by fine veinlets of chalcedony or quartz. Not so rarely in the fluorspar is observed the tendency toward the development of a columnar form or shelly-concentric concretion, similar to the fluorspar of the Kalanguy deposit.

A similar structure of the vein body exists in all three horizons of the main vein, and only sometimes the central part

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of the vein comes out and remains an unfilled cavity or the asymmetricalness of the vein is observed on account of the absence of some of its wall.

Thus, the vein body is poly-mineral, the genesis of the fluorspar, undoubtedly, is hydrothermal.

In a southern direction, not far beyond the limits of the southern drift of the third horizon of the No 2 shaft, the main vein, apparently, dies out, inasmuch as fluorspar is not encountered in hole No 8, which runs through here.

At the present time, the fields of shafts No 1 and 2 are almost completely worked out on the three horizons, and further operations depend on the timely performance of preliminary mining work on the lower lying horizons. Shaft No 3 works the second horizon and is carrying out developmental work on the third horizon. The sinking of the shaft of No 2 is finished, and now (1936) the cutting of the floor drifts is being carried out.

By means of prospecting in the main vein, the continuation of the vein along the dip up to 130.5 meters is established, which permits the calculation of the reserve of fluorspar for the entire time of the mine's existence. The thickness of the ore body does not vary with depth, apparently, inasmuch as the average figure brought out for the thickness in the whole deposit, equalling 0.72 meter, is confirmed by the average thickness in the three holes No 5, 6 and 7, which equals 0.75 meter (Table 15).

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Table 15

No of Hole	Depth of Hole on Slope, in Meters	Depth of Cut Vein Zone, in Meters		Thickness of Vein	Thickness Actual of Fluor-Thickness	
		On Slope	On Vertical	Zone on Vertical in Meters	Spar on Slope, in Meters	of Floor- spar veins in Meters
1	64.14	54.50	47.30	0.50	0.50	0.32
2 ¹	53.11	24.43	22.50	-	-	-
3	42.14	39.22	34.50	2.33	2.33	1.45
4	14.72	6.40	6.15	3.60	3.60	1.50
5	110.00	100.00	90.75	2.50	2.50	1.20
6	152.26	144.54	130.50	1.52	1.38	0.85
7	130.00	91.00	82.00	0.35	0.35	0.29
9	77.69	74.00	67.50	2.50	2.50	1.80

¹ Veins of commercial importance not encountered)

In Table 16 are cited the reserves on 1/IV, 1934

Table 16

Name of Vein	B	C ₁	C ₂	B + C + C ₂
Main	25,600	22,000	12,000	59,000
Sakhalinskiy	8,000	7,000	-	15,000
Σ	33,600	29,000	12,000	74,600

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Among the other deposits the Abagaytuy is distinguished by the presence of high quality fluorite on account of the insignificant content of silicic acid in it in the greater part of the deposit. Fluorspar with an average content of CaF_2 of nearly 90 per cent is distributed chiefly in the limits of the drifts of shaft No 2. To the North, in the region of shaft No 1, the content of silicic acid increases and the content of CaF_2 fluctuates within the ranges of 80 - 85 per cent. The section between pit No 7 and the "Sakhalinskiy" vein is considerably silicified and the content of CaF_2 on the average hardly exceeds 70 - 75 per cent. The "Sakhalinskiy" vein possesses, in certain sections, exceptionally high quality fluorspar; the most typical analyses are as follows: CaF_2 , 87.33 - 91.43 per cent; SiO_2 6.29 - 9.30 per cent.

Approaching the granite block the contents of SiO_2 in the vein increases.

In conclusion it should be noted that the comparative nearness of the mine to the railway (47 kilometers to the north-east of the Otpor station of the Molotov Railway) and the high quality of the fluorite in individual parts of the deposit means that serious attention should be given to the mine as a raw material base of the cryolite industry. As soon as a concentration plant is constructed in the Union or a deposit is located with high-quality fluorite, the Abagaytuy will become of secondary importance. A negative factor for the deposit is the absence nearby of construction and reinforcing materials, and also the increased inflow of water with depth (Table 17).

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Table 17

No of Hole	Interval on the Slope in Meters		Content in Percent	
	From	To	CaF ₂	SiO ₂
5	100.00	100.95	82.71	15.95
5	100.95	101.89	78.26	15.95
6	144.2	145.35	69.01	28.82
6	145.35	145.81	92.24	5.03
6	145.81	146.06	94.48	3.66

Note. It should be taken into consideration that the best parts of the fluorite in the root in virtue of the small content of SiO₂ possess little strength and more is exposed to deterioration during drilling.

The Bugutursk deposit is situated on the mound of that same name. The outcroppings of fluorspar that have been discovered are quartzitized in the highest degree.

ONON GROUP OF DEPOSITS

The Kuranzhinsk deposit is situated on the right bank of the Onon River, not far from Ust'Uly, 160-170 kilometers to the south of the Makaveyev station of the Molotov Railway; prospecting operations were carried out in 1931 by the Eastern Siberian Geological Trust for wolframite, and fluorspar was discovered incidentally.

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The vein of fluorspar occurs among clay slates and sandstones (J_2) with a trend north-east 40 degrees $\angle$ 55 degrees south. The trend of the vein is north-east 50 degrees $\angle$ 75 degrees south-east. The character of the fluorspar and of the deposit itself is completely similar to the Kalanguy.

The vein has been traced for a distance of nearly 225 meters. In the south-west it tapers out, passes over to a zone of clayey, kaolinized material with infrequent, small fragments of fluorite. In the north-east the vein disappears under detritus, and prospecting operation have not established its further continuation. The secondary rocks are kaolinized to a considerable degree.

The vein has been opened by eleven trenches and has been traced in depth by three pits. The pits and drifts which have been passed through indicated branching veins at a depth (up to 20 meters), forming a "horse tail". In pit No 2 the vein is divided into three veinlets with a general thickness of 0.5 meter. At a depth, pyrite appears in the fluorspar in small quantity.

The average thickness of the vein in the prospecting trenches reaches 1 - 1.2 meters.

The reserve up to a depth of 10 meters is expressed in category A_2 at 6 thousand tons.

Dul'Durginsk deposit is located 144 kilometers to the south of the Makaveyev station of the Molotov Railway, on the right bank of the Malyy Shabaralay River (to the north of the preceding deposit). The fluorspar approaches the high-tem-

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perature type. According to the data on the Eastern Siberian Geological Trust, the reserves in the categories are the following: B - 1,950 tons, C - 6,500 tons.

The fluorspar is distinguished by high quality and is characterized by the following data: CaF_2 , 96.52 - 97.71 per cent; CaCO_3 , 3.10 per cent; Fe_2O_3 , 0.62 per cent and SiO_2 , 2.28 - 4.80 per cent.

The Sellovsk deposit is located near the Sellovay siding of the Molotov Railway and is represented by two territorially disconnected veins, one of which bears the name of Dagoy deposit, and the other Sellovsk deposit.

The Dagoy section is situated 3 kilometers to the south-west of the siding referred to, on a dirt road. Dagoy is coordinated to a strata of Mesozoic sandstones and slates, represented by coarse arkose sandstones, which considerably predominate and alternate with the clay slates. The trend of the rocks is north-east 20 - 50 degrees with a sharp dip to the south-east. The deposit is enclosed in a fault fracture with a trend of 90 - 110 degrees and a dip to the south, from which branch out a number of small fractures which usually are not parallel to it.

According to the form of occurrence of the ore body, the deposit may be considered as a vein; however, in view of the presence of numerous apophyses and branchings from the basic vein and of the presence in direct proximity with the vein of unusual breccia, often mineralized, it is rather difficult to

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delimit the conception of the vein from the ore zone. By this is explained the extremely inconstant thickness of the ore body, which fluctuates from 10 - 15 centimeters to 2 meters. The extent of the whole vein is nearly 140 meters.

Changes of the secondary rocks in the sandstones lead to the formation of pores and the kaolinization of the feldspar, but in the slates occurred the formation of leaflets of biotite and the transformation of them into a clayey, porous mass. On near contact with the vein the rocks are silicified, which is especially noticeable on the under side.

The Mineralogical composition of the vein body is quartz and fluorspar. The fluorspar is compact-crystalline, chiefly green and more rare of violet color and colorless.

The content of CaF_2 is comparatively high and more often fluctuates from 80 to 90 per cent. During exploitation, a considerable amount of fines is obtained.

The deposit was opened in 1933, when its exploitation was begun by the underground method, with the extraction of 2 - 3 thousand tons per year of commercial product.

At the present time (1936), the reserves in category B + C hardly exceed 5 thousand tons.

The Sellovsk section is situated 1.5 kilometers to the west of the siding of that same name, and during the period 1922 - 1924 was prospected and exploited.

The vein, with an extent of 30 - 40 meters and a thickness of 2 meters (maximum), has a trend north-west 280 - 300

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degrees / 70 degrees south. It occurs in those same rocks and has that same mineralogical composition as the Dagoy.

At the present time the deposit has no commercial importance.

MINERALOGIC -PETROGRAPHIC CHARACTERISTICS
OF THE DEPOSITS OF TRANS-BAIKALIA

A. V. Gulyayeva

The mineral composition of the fluorspar deposits of south-eastern Trans-Baikalia is distinguished by an extremely limited quantity and equality of the constituent components. Predominant in it are fluorspar and the mineral groups of silica, which in amount usually comprise 95 - 98 per cent of the vein composition. Besides these are encountered barite, calcite, adular, mineral groups of kaolinite and zeolite, but quantitatively they are less intrinsic and are present only in individual deposits. By this also is limited strictly the list of primary minerals known at the present time. Thus, a distinctive characteristic of the deposits of Trans-Baikalia is the complete absence in them of primary ore minerals, in particular, zinc sulfides, lead and copper, common, perhaps, for the majority of fluorspar deposits of the world, among them also almost all of the remaining deposits of the Union. Of the sulfides, almost everywhere pyrite is present, but it, however, cannot be considered as representative of the ore foundations.

The indicated feature of Trans-Baikalia is extraordinarily characteristic and is firmly maintained in all deposits, of which over 20 are known at the present time. This circumstance

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puts forward south-eastern Trans-Baikalia as a fluorspar province with a characteristic, very sustained mineral type of deposit, which, with complete truth, may be called the Trans-Baikal type.

In spite of the limitation of the number of vein components, the individual deposits are all considerably different, one from the other. The differences are expressed in the degree of dispersion of those or other components, in their inter-relationships with one another and their mineralogical characteristics. All the numerous deposits of Trans-Baikalia can be divided into three types according to mineral composition:

(1) "Mono-mineral" fluorspar, with a typical representative in the Kalanguy deposit, Taminga II and Kuranzhinsk;

(2) Quartzitic-fluorspar, to which belongs the Solonech deposit and an entire series of small deposits;

(3) Quartzitic-baritic-fluorspar, in which barite, together with quartz and fluorspar, play a large role. To it pertain the Abagaytuy, Taminga I and, partially, the veins of Ninth Friday.

All are closely connected and, evidently, represent the products of definite stages of a single process of mineral-formation of hydro-thermal solutions.

KALANGUY DEPOSIT

Structure and Composition

The Kalanguy deposit is coordinated to the fracture of

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a fault, in the middle of an alternating sandy - clayey stratum, which is dissected by veins of porphyrites. The fluorspar with its accessory minerals fills the intervals between the fragments of breccia and stands out in irregular or straight-line fractures in the upper or under sides, accompanied by short apophyses of slight thickness, usually coordinated to the upper side; the under side is cut by one or several straight-line faulted surfaces.

The Kalanguy deposit is a sharply expressed mono- mineral deposit. The fluorspar is almost a single vein mineral, comprising on the average nearly 70 per cent of the vein mass. Different modifications of silica - chalcedony, opal, quartz, more rarely pyrite - of the other vein components are present in insignificant quantity. Second place after fluorspar in the structure of the vein is occupied by fragments of secondary rocks and the products of their disintegration in the form of minerals of the group of kaolinite and clay products. The latter, basically, specify a relatively low content of CaF_2 in the vein. Besides this, the following secondary minerals are encountered; limonite, hematite, nontronite and jarosite, which have only mineralogical importance.

Extremely characteristic, and at the same the predominant form in which fluorspar occurs in this deposit, are the columnar varieties of it in the concentric-shell-like or straight-line-ribbon-like structure of the vein.

Fluorspar with sharply expressed columnar structure and in conjunction with cockade structure, also extremely complete, is not encountered very often and nobody has described it. There-

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fore, we shall dwell on it more in detail.

The vein body in its main part consists of an aggregate of cockades, which have a concentric-shell like structure, the intervals between which are filled with coarse or fine breccia of secondary rocks, cemented by fluorspar. Straight-line veinlets of fluorspar are another structural form of vein, and which are a symmetrical or unsymmetrical ribbon formation. The latter are coordinated usually to the casing parts of the vein and on one side interlock with the cockade part of it, and on the side of the lateral rocks produce tapering and branching veinlets between fragments of breccia, and the vein body in this manner passes over on the upper and under sides into fluoritized breccia.

In the breccia zone the fluorspar tended to crystallize also in the form of cockades. The constant presence, together with the veinlets, of small cockades and nuclei of them, bears witness concerning this. Thus, all three structural varieties of ore are closely connected to one another, and to isolate them spatially does not seem possible; it is possible only to speak concerning the predominance of ore of that or another structure in the definite parts of the ore body, to wit: the cockade structure predominates in the vein and is developed, simultaneously, into secondary breccia; veinlets, peculiar to the quartz parts of the vein, are encountered also among the breccia and cockades; finally, sections with breccia structure, besides the walls of the veins, are prevalent in that its cockade part, filling in places the intervals between the cockades and occupying a subordinate role.

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The cockades are developed especially near the under side of the vein, when, as near the upper side for the most part, a straight-line-ribbon-like veinlet passes through. In places are observed casings of soft yellow or brown clay. They are present, usually, at the contact of the vein with shattered porphyrites, being absent in other sections.

The ribbon-like veinlets and cockades are very similar to one another in their nature, consisting in both cases of strips of columnar fluorspar, crystals of which on its long side always are situated perpendicularly to the overgrowing surface.

Structure of the Cockades

In the center of the cockades as a core usually is found a fragment of secondary rock - sandstone, clay slate or porphyrite, from unchanged to completely crumbling (Figure 1). More rarely the core forms fragments of ribbon-like-columnar fluorspar or fragments of cockades. The size of the cores, as the cockades themselves too, fluctuates within broad limits. Usually they do not exceed several centimeters, but sometimes the size.

Figure 1. Structure of the Cockade. Natural Size

a - Core; b - Columnar Fluorspar; c -Phosphorous* aggregate.

[*Errata. Page 72: Legend to Fig. 1 Phosphorous should read porcelain]

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of them reaches up to 0.5 - 1.0 meter. The diameter of the cockades in the majority of cases is from several to 30 centimeters, sometimes up to 1 - 2 meters. It should be noted that the size of the core, as a rule, is several times less than the body of the cockade. Especially large cockades develop on account of the core, as when the fluorspar layer in them does not exceed 0.15 - 0.20 meter. The body of the cockades consists of alternating concentric-shell-like scales of columnar or tree-like-columnar, transparent fluorspar of various colors and scales of white or gray color of compact porcelain-like structure. The latter consists of fine grains of fluorspar, in which are included scales of kaolin, sericite, turbid pelitic products and round fragments of secondary rocks. These two varieties in the cockades repeatedly alternate, whereupon the growth of the cockades always begin with a small-grained, compact aggregate. Scales of pure columnar fluorspar occupy the predominating role in the cockades, the width of the former or, what is the same, the length of the columns reaches 10 centimeters and more, as when the scales of the small-grained aggregate possess a width up to part of a millimeter and not above several millimeters; the latter usually do not cover all the surface of the cockades, but only the part of them thinning out on both sides. In the process of growth the cockades, evidently, repeatedly were inverted. The intensive growth of fluorspar, now from one, now from the other side is evidence of this, at the same time as the growth from the opposite side, being a place of contact with the neighboring cockade, ceased or slowed down.

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At the same time, according to the degree of growth, the originally existing numerous small cockades combined into a few large ones; when the intervals between the neighboring cores completely were filled with vein material, the solutions covered the available concretions of small cockades, continuing to deposit the fluorspar already around this concretion, which assumed the role of the core.

As has already been indicated, layers of the porcelain aggregate form incompletely developed scales of cockades, and also fill the cavities between neighboring cockades. The fragments of secondary rocks enclosed in the aggregate, scales or sericite and kaolin represent a mechanical admixture, which developed in the mineral solution in suspension and then precipitated simultaneously with the deposit of fluorspar. This is confirmed by the fact that they always, in the greatest quantity, accumulate in the lower parts of the porcelain layer, occupying the settling sections on the surface of the cockades - the cavities between adjacent blocks of columnar crystals, connectors between adjacent cockades etc.

The frequent alternation of the scales of columnar fluorspar with the scales of the small-grained aggregate, which is accompanied at the same time by precipitations of mechanical particles, bears witness to the sharp changes of the physico-chemical conditions in the process of formation of the ore body. These changes, evidently, took place more or less suddenly, because the large columnar crystals alternate abruptly with the small-grained aggregate. The small-grained fluorspar, in its turn, according to the degree of growth of the cockade, passes

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over into columnar fluorspar, but already by means of the enlargement and lengthening of the grain. Simultaneously with this, the deposit of mechanical admixtures, also, gradually ceases.

At the same time there are no indications of any break in the growth of the cockades, or the more so there are no indications of their disintegration. Under the microscope it is seen that the ends of the columnar crystals under the layer of the small-grained aggregate always possess normal angles and uniform facet-ways, and there is no basis for speaking about the periods of complete cessation of mineral-formation (Figure 2).

The simplest and most acceptable explanation of this alternation of periods of deposit of large-columnar formations with the small-grained aggregate is the assumption of a periodical exposure of the vein cavity in the process of formation of the vein. Standing on such a point of view, it is possible to explain much, which seems on first sight unintelligible. Let us imagine that the fracture, filled by the first portion of vein materials, for one reason or another again is uncovered. It is natural that, in addition, the existing pressure of the rising solutions falls and, they even assume a descending movement. The suspended mechanical particles, which, undoubtedly, could be entrapped by the solution at the time of circulation in the fractures and among the breccia, are turned downward and settle, occupying different cavities, surfaces with small angle of slope, generally congested and quiescent sections. At the time of the change of pressure, the temperature and concentra-

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tion of the solutions were changed, and, consequently, the conditions of crystallization were changed - their precipitation from the solutions was accelerated; this found its expression in the alternation of the large-columnar fluorspar with the small-grained. It is completely natural that during repeated exposure of the fracture from the side of the suspended wall fragments of secondary rock broke away and slid into the fracture, fragments which earlier were formed of fluorspar and further became a center of crystallization of the new cockades or were pressed between the new scale and the previous surface of the cockade. By this it is possible to explain the presence of cockades with cores of fragments of columnar fluorspar or fragments of cockades.

In a similar manner, to a considerable degree, it is possible to explain also the "suspended" position of the core in the vein. As has already been indicated, the size of the core of the cockade for the most part is several times less than the thickness of the encompassing crust of fluorspar, and during the withdrawal from it of all fluorspar the cores would appear to be suspended in the air at a distance of 0.5 meter from one another.

One of the reasons for such a position of the core un-

Figure 2. Transition of columnar fluorspar (light) into the porcelain layer (dark) X 35, "nik. - ."

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conditionally is the displacement of the breccia, especially the finely-fragmented groups of it, by fluorspar, which generally is widely developed in the deposit. At the same time there is no data telling of the metasomatic nature of all of the fluorspar, in particular of the large-columnar aggregates of it. Usually, the metasomatic nature of fluorspar is established sufficiently easily in the relics of displaced material and buried structure. This follows from the observations of metasomatism in the walls of the veins both at the Kalanguy deposit and also at other deposits. Open space for the growth of cockades, evidently, was created owing to the uncovering of the fracture and the crystallizing force, which in addition removed the cockades from one another.

After the uncovering and the intensive sedimentation connected with it of the suspended particles, together with the small-grained fluorspar, the disturbed physico-chemical conditions gradually were reestablished, the settling of the mechanical admixtures gradually ceased, and again the crystallization of the large-columnar fluorspar took place until the next uncovering of the fracture. The general appearance of the deposit, which bears the character of a formation of small depths and in conditions of low-temperatures, does not contradict such assumption, but rather confirms it.

Description of the Minerals

The fluorspar forms in this manner cockades or veins, more rarely individual impregnations, crusts and nodules.

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It is rather alike, light-colored, relatively transparent, columnar. A somewhat lesser role in the structure of the vein is played by the semi-transparent variety of fluorspar, "yel'chatiy", as also the compact, small-grained, milk-white fluorspar, which is accompanied usually by the mineral group of kaolin. As relatively rare findings in the vein also are encountered the small-crystalline, lilac-violet and transparent large-crystalline variety of green color.

Columnar fluorspar is individual, indivisible concretions which intertwine in parallels and stretch along the axis of the third order (Figure 3), while the long side of the ray is located perpendicularly to the surface of growth.

In cross-section the columns have the form of irregular polyhedrons, the number of sides of which does not exceed six. These limitations do not match up to any of the elements of symmetry of fluorspar and are explained only by the surfaces of contact with adjacent crystals. Their diameter, as a maximum, equals 0.5 and often decreases to a fraction of a millimeter. In the limits of one concentric layer the diameters of parallel rays are usually equal to each other. But their sizes in the different layers of one cockade may be most various. In the same way the size of individual rays is variable too in the longitudinal section, fluctuating from a fraction of a millimeter to 10 - 20 centimeters. The surfaces of contact of the individual columns are completely rectilinear sometimes, but sometimes during examination under binoculars they appear to be bearing on themselves a fine hatching, oriented perpendicularly to the direction of growth of the individual rays of some facets, possibly,

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Figure 3. Columnar fluorspar; black dots are inclusions of kaolin. X 5 - "nik".

facets of the cube and octahedron.

The crystallization of each layer of columnar fluorspar is completed by the formation on the tips of the individual rays of three facets of a cube, which are arranged near one of the apexes of the cube, to which very rarely is attached a facet of an octahedron. More often than a facet of an octahedron, near the apex of the cube appear the facets of a tetragonal-octahedron, developed so strongly in certain cases that they completely displace the facets of the cube.

Each separate layer of columnar fluorspar in the cockade usually is not a finished circle. Sometimes they received a more one-sided development in the form of an arc, with considerable thickness in the center, gradually diminishing toward the ends. But certain of them have irregular swellings or cavities, which are, apparently, traces of contacts with adjacent cockades.

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The number of concentric layers in the different cockades is dissimilar. Sometimes only certain layers are developed, but sometimes their number reaches 20.

The color of the columnar fluorspar always is expressed by pale tints of yellowish, rose, crimson or smoky colors. Often it is also colorless. The individual rays of it rarely have one uniformly distributed color; in the majority of cases they are colored either in different colors or are colored in one color, but with a different intensity in the separate parts. These different colors are arranged with parallel belts of the most various sizes, being oriented always perpendicularly to the ray. These variations of color or their intensity take place simultaneously in all the parallel rays of the given layer, which leads to the formation in the cockades frequently of alternating, differently colored concentric circles.

The next variety of fluorspar, the "yel'chatiy", is observed chiefly in the peripheral parts of the cockade, forming, in the majority of cases, after the columnar fluorspar. It is also a radiating fluorspar, but, in distinction to the columnar, the individual rays have small sizes in length and form rather complex concretions. Usually in the direction of the columnar fluorspar, one short ray of yel'chatiy fluorspar begins to grow, the diameter of which is considerably less than the diameter of the columnar fluorspar. Sometimes this ray is not an entire crystal, but is a concretion of small, round grains which grew on one another in one direction. From this ray or the links of it, represented by individual grains, similar rays begin to accumulate

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on all sides, leading to the formation of a concretion, in cross section reminiscent of the structure of fir branches. Such formations of yel'chatiy fluorspar sometimes occupy the upper layer of the cockades, reaching several centimeters in thickness. But in the majority of cases they form small nodules with a round surface. On several of them under binoculars, it is possible to note that each separate ray and its final link is a cubical crystal particle. Sometimes the size of such nodules increases so much that already without difficulty it is possible to view on their surfaces an irregular concretion of cubes. During the increase of the sizes of these nodules their structure in the form of yel'chatiy concretions is disturbed; the separate nodules fuse together, forming compact, thin crusts of crystals in the form of cubes with small irregular concretions of these crystals rising over them. An extremely curious formation of yel'chatiy fluorspar was observed by us in an open pit in the northern part of the vein. In a small cavity, from its upper part hanging downwards were small, individual rays of yel'chatiy fluorspar up to 1 centimeter, reminiscent of typical formations of stalactites. This fact, without doubt, speaks for the fact that the crystallization of yel'chatiy fluorspar took place partially from descending solutions, apparently at very low temperatures and pressures.

The yel'chatiy fluorspar is colored in still lighter rose and yellowish tones and often is colorless or milk-white. Owing to the small-grained structure and abundant inclusions, it is semi-transparent.

The fine-grained, compact, porcelain-like varieties of fluorspar are white, of various shades, participating in the cement of breccia, in the wall sections of the vein and in the

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structure of cockades; actually, they do not represent pure fluorspar, but always contain some amount of admixture. Usually they consist of small, isometric grains of fluorspar from 0.005 to 0.01 millimeter, among which are included scales of kaolin, sericite, the remains of fragments of secondary rocks and, in individual cases, spindle-shaped formations of quartz. Apparently, the presence of these admixtures also gives to this aggregate a porcelain-like character with a dull or earthen finish. Here the fluorspar usually does not possess crystallographic forms; sometimes, during the development of crystals in the side of cavities, facets of a cube are observed. In the cockades, according to the size of the growth of its concentric layers, this small-grained fluorspar gradually passes over into columnar fluorspar by means of a gradual enlargement and elongation of the grains.

Obviously, to one of the later generations at the Kalanguy deposit pertains also the variety of fluorspar which is colored in clear lilac-violet color. It forms thin crusts in the fractures, chiefly on the edges of the vein or on the surface of small cockades. The individual, very small crystal particles, are represented always by cubes, complicated by facets of other forms.

The large-grained and compact-crystalline varieties of green color at Kalanguy are observed comparatively rarely. They are encountered in small veinlets in the walls of the vein and, apparently, were given off earlier by columnar varieties. On the other hand, in the veins to the north of the main vein, the compact-crystalline and large-grained, clearly colored varieties are very common. Here the fluorspar is in close paragenetical con-

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nection with quartz.

Data on the physical properties and chemical composition of fluorspar are cited in an article by A. P. Ponomarev. But here we will note only that the columnar varieties are distinguished by weak luminescence and during heating weakly cracks.

The minerals of the silica group in the structure of the vein body play an insignificant role; they are represented here almost exclusively by the cryptocrystalline varieties, chalcedony and hornstone, and in lesser measure by short-prismatic quartz and opal. These two moments, together with the columnar structure of the fluorspar itself, comprise the characteristic features of the Kalanguy deposit, peculiar to the final stages of mineralization of other deposits.

According to time of formation they are divided into two generations - prior to fluorspar and after it. The latter generation is expressed exclusively by chalcedony and opal, which form crusts on the surfaces of cockades and veinlets in port-mineral fractures and, apparently, represent the sedimentation of surface waters. The formation of the first generation completely precedes fluorspar and is coordinated to the fluoritization of the breccia in the walls of the veins. Here, hornstone quartz is most prevalent, with rapid transitions, within the limits of one section, to chalcedony, on the one hand, and to short-prismatic quartz, on the other. The latter, in the form of microscopical crystals, grows on the walls of cavities of breccia, completing the process of its "orogovikovaniye".

Opal among the fluorspar can be observed under the micros-

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it and being involved in re-deposited form in the structure of the cockades in the porcelain-like layers described above.

Observations under the microscope indicate that the formation of kaolin minerals occurred in two stages, which are rather clearly established. The basic mass of them was formed in the initial stage of change of the wall rocks, simultaneously with intensive sericitization. At this time, as a rule, are separated out either turbid, dust-like clay products, usually a priori accepted for kaolin, or compact, mealy accumulations, weakly active to polarized light, with such small sizes of the individual scales that they are detected with difficulty at the time of greatest magnification.

According to analyses borrowed from the account of P. P. Pilipendo, these varieties are characterized by the following composition (Table 1).

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Table 1

	I	II	II
	Yellow	Light-gray	White
	Variety,	Variety,	Variety,
	Per cent	Per cent	Per cent
SiO ₂	53.01	64.71	66.85
TiO ₂	0.67	0.38	0.25
Al ₂ O ₃	28.12	22.17	22.16
Fe ₂ O ₃	5.23	2.68	1.78
FeO	0.17	0.16	0.13
MgO	0.84	0.38	0.33
CaO	1.27	0.57	0.33
Na ₂ O	0.33	0.10	0.23
K ₂ O	1.15	1.98	1.59
F	None	None	None
Loss during			
Calcination	9.24	6.70	6.93
	100.3	99.83	100.58

The second stage of formation of kaolin is connected with the beginning of sedimentation of fluorspar, namely, with the period of intensive displacement by it of fragments of transformed wall rocks. It is characterized by the appearance of clear-crystalline kaolin, which forms rather large scales and vermicular crystals, completely identical to the kaolin of the Abagay-tuy deposit, described below.

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They are present constantly and in considerable quantity, together with remains of fragments of wall-rocks among small-grained fluorspar, which is a component of the core of the cockades and the cement of the breccia in the walls of the vein. In fluorspar, they are distributed irregularly, sometimes in the form of isolated scales, sometimes in the form of irregular accumulations or forming concentric accumulations (Figure 4). In those cases when the formations of fluorspar possess crystallographic forms, the accumulations of kaoline scales form parallel belts, oriented along one of the facets of the crystal. Usually, these scales in the greatest amount accumulate along the borders of the fluorspar with the remaining wall rocks, never being present in the fragments themselves.

The constant connection of the appearance of this kaolin with the processes of displacement of the wall rocks by fluorspar leads to the conclusion that under the influence of fluorine compounds, part of the kaolin material and sericite of the transformed rocks was re-crystallized into "large-crystalline" kaolin.

Figure 4. Inclusions of kaolin (dark concentric layers) in fluorspar X 40, "nik. -."

Scattered occurrences of it and, moreover, together with

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remains of fragments of wall rocks, did not afford the possibility of obtaining the pure product and or to study it in detail, but an analogy with the Abagaytuy this variety can be referred to the "dikit".

Pyrite belongs to the number of minerals which are comparatively rarely encountered, but, evidently, its original role in the deposit was considerably greater, inasmuch as the formation of numerous hydrate compounds of ferrous oxide it is necessary in great measure to refer to the disintegration of pyrite.

Most often it is encountered in the form of impregnations in the slates, in the walls of the veins or the cores of the cockades. Now and then it forms impregnations in the vein itself among the columnar fluorspar of the cockades. The crystals are always in the form of cubes. Inasmuch as similar impregnations are observed in the slates of the region and without a connection with the ore vein, it is true, in lesser amount, evidently, that the formation of it is not connected with the process of fluorspar formation, but represents the product of the reduction of the ferrous sulfate of the descending waters by the carbonaceous material of the slates.

Marcasite is encountered still more rarely than pyrite, and exclusively in the fractures in the slates near the ore body. It forms fine, gold-colored deposits; the crusts often have an opalescent iridescence, and sometimes are found together with small veins of quartz. It was not encountered in the ore vein itself.

Hematite is encountered rarely in the form of kidney-

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scales on the surface of the cockades. Individual nodules, together with veiny structure, possess coarsely shell-like and wedge-shaped surfaces. Sometimes the upper concentric layers of the nodule pertains to goethite.

Hydrate compounds of ferrous oxide are extremely prevalent in the deposit. The most common of them is limonite, the least common are turgite and goethite. They are encountered almost everywhere, but nowhere do they form significant accumulations. In the majority of cases they are fine deposits or films, which sometimes cover even the separate rays of columnar fluorspar. More rarely there are small sinters or dendrites of extremely fantastic forms.

Compounds of ferrous sulfates were found by us in the form of pale-yellow, sometimes weak-green, accumulations, penetrating into the small-grained aggregate of kaolin. Reactions with the blow-torch indicated the presence of SO_3 . The absence of a possibility of obtaining pure material did not permit the carrying out of an exact determination, but, apparently, the material in question pertains to jarosite.

Nontronite rarely is encountered in the ore body of the Kalanguy deposit. Most often it is observed in the walls of the vein in the fractures, forming small accumulations of a dirty-greenish color. It is encountered also on the surface of the cockades, covering the crystals of fluorspar themselves. P. P. Pilipenko reports interesting relationships of nontronite and fluorspar. Leaflets of nontronite, covering the crystals of fluorspar on the facets (100), adhere to them, forming, as it

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were, lattice structures, which indicates the simultaneous crystallization of both minerals at low temperatures.

The calcite in the ore body is insignificantly small; it is of secondary formation and is connected with "gipergennyi" processes. It forms small fine crusts and sinters or powdery accumulations. Its paragenesis with opal is interesting. The latter usually covers the powdery accumulations of calcite with a fine crust, the calcite being impregnated with limonite.

Judging by the structure and composition of the vein, the deposit was formed at small depths. The circulating solutions, evidently, were of equal composition and weak. Besides the fluorine compounds, in the initial phase they contained carbonic acid, which was instrumental in the kaolinization of the lateral rocks. Signs of the introduction by the solutions of silicic are absent. The small quantity of it, which is present in the deposit, most quickly of all proceeded from the lateral rocks in the process of displacing them.

CHANGES OF WALL ROCKS

Changes of the wall rocks under the influence of mineral solutions are expressed in sericitization, kaolinization, silicification, limonitization and fluoritization. The zone of change reaches 2 -- 4 meters.

Kaolinization develops especially intensively and is characteristic for this deposit. The rocks in the walls of the vein usually are so crumbled that it is not always possible to

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establish their original character; the feldspars are transformed entirely into the aggregate of kaolinite, sericite and quartz; the biotite for the most part is sericitized, less frequently being replaced by chlorite. As has been shown above, the formation of kaolin occurred in two moments: into a beginning stage of change of the wall rocks, in common with sericitization, and into a period of metasomatic fluoritization of the wall breccia.

The silicification of the wall rocks at Kalanguy, in comparison with other deposits, is developed weakly. Close-grained rocks, macroscopically having begun as silicified rocks, under the microscope in many cases proved to be fluoritized. Occurrences of silicification appear more clearly in the under side in comparison with the upper side. Here, the chalcedony or hornstone quartz penetrate through the small cracks of the breccia, cementing, and in places replacing, the fragments of wall rock. Regarding the latter, the "obsosanny" borders of fragments and the frequently observed buried structures bear witness. In the clay slates, the silicic acid, as well as the fluorspar, penetrates along the surface of cleavage, causing the silicification of them in layers.

Limonitization also plays an insignificant role in view of the small quantity of ferruginous minerals in the rocks. It is expressed in the formation of brown ferric oxides during the decomposition of biotite and in the oxidation of pyrite, which is encountered frequently among the clay slates.

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Minerals	Hydrothermal Phase	"Gipergenny" Phase
Chalcedony, Quartz		
Fluorspar		
Kaolin		
Opal		
Pyrite		
Limonite		
Jarosite		

Figure 5. Table of the sequence of formation of minerals for Kalanguy.

Fluoritization follows silicification, being the last stage of change of the wall rocks. It develops sharply in the under side, which is characterized by a great deal of shattering, and develops both in the ordinary cementation of breccia and also in the widely developed occurrence of replacement. The width of the fluoritized zone is up to 1.5 - 2 meters, with a gradual decrease of its intensity.

The components of it which disintegrated earlier are also exposed to replacement for the most part in all rocks.

Therefore, depending on the composition and structure of the rocks, a different process of fluoritization is observed. Thus, in the porphyrites, the sericitized or chloritized phenocrysts are replaced, in the beginning, by fluorspar. During the further course of the process, the basic mass of the porphyrite is included, also its sericitized part, for the most part, and then is preserved as

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Minerals	Hydrothermal Phase	"Gipergenny" Phase
Chalcedony, Quartz		
Fluorspar		
Kaolin		
Opal		
Pyrite		
Limonite		
Jarosite		

Figure 5. Table of the sequence of formation of minerals for Kalanguy.

Fluoritization follows silicification, being the last stage of change of the wall rocks. It develops sharply in the under side, which is characterized by a great deal of shattering, and develops both in the ordinary cementation of breccia and also in the widely developed occurrence of replacement. The width of the fluoritized zone is up to 1.5 - 2 meters, with a gradual decrease of its intensity.

The components of it which disintegrated earlier are also exposed to replacement for the most part in all rocks.

Therefore, depending on the composition and structure of the rocks, a different process of fluoritization is observed. Thus, in the porphyrites, the sericitized or chloritized phenocrysts are replaced, in the beginning, by fluorspar. During the further course of the process, the basic mass of the porphyrite is included, also its sericitized part, for the most part, and then is preserved as

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quartz.

Figure 6. Speckled replacement of schists (gray) by fluorspar (dark). X 80 magnification.

For the clay slates, possessing a more homogeneous composition, a speckled replacement in layers is characteristic. Here, the solutions penetrate through the surfaces of cleavage, and replacement begins from the surface in numerous individual centers (Figure 6), where the fluorspar forms irregular phenocrysts with extremely sinuous outlines. During the further development of the process, they are enlarged, unite with one another and separate the rock into separate fragments, creating in this manner metasomatic breccia inside the structure. In the sandstones, the process of fluoritization is less clear, but judging by residual material, into the first line in it the material of the cement and sericitized grains of feldspar is replaced. In all cases, quartz is the most stable, but, evidently, it, also, is partially replaced. Regarding this, it is possible to judge by the sinuous, as though "obsosahnyy" [sucked out?], edges of its grains.

In the core of the cockades, replacement of the fragments takes place in similar fashion to that described.

The fluorspar, which forms during the replacement of the wall rocks, is rarely pure; it almost always contains inclusions of kaolin in the form of relatively large scales and their concretions. At the same time the behavior of the sericite is interesting. During the time of chertization of the breccia, it usually is preserved,

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developing into hornstone as a residual material. But during fluoritization, according to all data, it represents one of the most easily replaced objects. These two phenomena, the almost complete disappearance of sericite during the replacement of the rock by fluorspar and the appearance in the latter of kaolin, involuntarily leads to the thought that the sericite here passed over into kaolin.

In order to illustrate the chemical changes, we cite analyses of sandstone, borrowed from the manuscript account of P. P. Pilipenko (Table 2)

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TABLE 2

	I	II
	Green Sandstone, taken 20 meters from the edge of Cut No. 8	Changed Sandstone of the northern edge of Cut No. 8, near the vein
SiO ₂	69.04	80.00
TiO ₂	0.52	0.51
Al ₂ O ₃	14.43	10.10
Fe ₂ O ₃	0.93	0.49
FeO.....	2.46	0.51
MgO.....	0.49	0.85
MnO.....	0.05	Traces
CaO.....	1.73	"
Na ₂ O.....	3.69	0.04
K ₂ O.....	2.21	2.42
H ₂ O _f	2.12	3.43
H ₂ O ₋	0.23	0.55
P ₂ O ₅	None	None
CO ₂	1.09	0.94
SO ₃	0.10	0.03
Volatile substances..	0.24	0.25
	100.49	100.12

As seen from the analyses, the changes lead to the carrying away of Na, Ca, Fe, partially of Al, and to hydration. Potassium

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remained in invariable quantity, being maintained in the form of sericite. The increase in the content of silicic acid, evidently, is explained by its concentration resulting from the carrying away of the components indicated above, since there are no signs indicating the slightest important addition of silicic acid by the solutions.

It should be noted that the different rocks are changed dissimilarly. The strongest sericitized and kaolinized are the porphyrites of the upper side, having lost completely the initial appearance. The sandstones, also, are disintegrated extremely intensively, although somewhat less. The clay slates are the best preserved, assuming a light color as a consequence of kaolinization and the oxidation of the carbonaceous substance but always retaining their structure.

ABAGAYTUY DEPOSIT**Structure and Composition**

The deposit consists of the so-called South field with one main vein and the North field, which consists of numerous short and thin, branching veins. The veins occur near the contact of the young post-Jurassic granites with the labradoritic porphyrites, for the most part among the latter, and in individual cases in the granites themselves. In composition, it is, basically, quartzitic-fluorspar veins with a predominance sometimes of the one, sometimes of the other component. To them are added in places, barite, zeolites, kaolinite and calcite in considerable quantities. Besides these, fragments of wall rocks, the clay products of their disintegration, and different secondary minerals are involved in the structure of the vein body.

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The structure of the vein is symmetrical-banded and has the form represented schematically in Figure 7.

Figure 7. Scheme of the structure of the vein:

1 - quartzitized breccia of porphyrite; 2 - quartz and chalcedony; 3 - fluorspar; 4 - barite; 5 - kaolin-fluorspar aggregate.

A fringe of small-grained quartz or chalcedony from several millimeters up to 10 centimeters thick serves with the casings. Farther toward the middle of the vein, from both sides, run the alternating bands of various-colored fluorspar and that same small-grained quartz. The middle of the vein most often of all is filled with quartz; quite a few parts are also empty, lenticular cavities of little length up to 10 meters in length and 2 meters in width. In many cases, these cavities, which remain clear during the first stage of mineralization, are filled by later formations. In such cases, on the walls of the cavities in the banded fluorspar, druses of coarse crystals of barite are formed, at the present time almost entirely leached out. Then, occupying the middle of the vein, partly on account of the remaining cavity, but partly at the spot of the leached out barite, together with other clay products, a porcelain-like kaolin-fluorspar aggregate of white or gray color was deposited. Both the empty cavities and also the baritic and kaolinic fillings of them are coordinated to the places of bulging of the vein exclusively, where an increase in thickness occurs on their account. Inasmuch as the largest bulges are found in the southern part of the main vein, then to this same section are coordinated also the thickest segregations of barite and kaolin-fluorspar aggregate. In sections with an average

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normal thickness and in places of reduced width, these components separate out completely or partially; in certain cases here small empty cavities are preserved, but usually quartz occupies the middle of the vein. The indicated structure of the vein is complicated by the appearance in the middle of the banded quartzitic-fluorspar part of the vein, in individual parts of it, of a formation of mineral of thinly-laminated, almost leaf-like structure. The latter in the process of mineralization was entirely replaced by quartz and fluorspar and is determined by the pseudomorphic structure of the latter. Judging by the structure, this was laminated calcite or barite or perhaps both. In the yields of shaft No. 3, both minerals are found in very similar laminated forms; therefore, it is difficult to decide to what the indicated pseudomorphic forms belong. Inasmuch as the laminated barite, undoubtedly, is original, and it is impossible to say this about the calcite with assurance, we attributed all similar formations to barite.

Judging by the pseudomorphoses, the laminated mineral in the upper horizons of the deposit plays a small role; it is encountered in the form of single seams and small banded formations, parallel to the bands of fluorspar and quartz. In the deeper horizons, 100 meters below the surface, according to the given drill hole, in the composition of the vein body it occupies a very large place. In hole No. 6, which cuts through the vein at a depth of 130 meters on the vertical, the central part of the vein has a thickness of 0.65 meter and is entirely built up by pseudomorphic fluorspar, which comprises $\frac{2}{3}$ of the whole thickness at this point. On the other hand, the symmetry of the vein itself is broken, which is a consequence

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of the disappearance of one of the wall parts or of the inroads of large fragments of wall rock, which dissect it into several branches, becoming asymmetrical-banded.

Together with the straight-line-banded in the vein, cockade accretions also are encountered. The latter also always are coordinated to the thick bulges and are closely connected with the straight-line-banded part of the vein, directly passing over into it in the walls, while in the middle, into the side of the cavity, project protruding blocks. The formation of them, evidently, is dependent on the flowing of the solution around the fragments of wallrock which fell into its way. The cockades have a somewhat elongated form (0.6 - 1.0 meter in size) and are built up by fluorspar with a weakly expressed radial-columnar structure, among the crusts of which now and then are located fine crusts of small-grained quartz or chalcedony.

Description of the Minerals

In the quantity of primary vein minerals the Abagaytuy deposit is the richest among the deposits of Trans-Baikalia. At the present time there are recorded here: fluorspar, quartz, chalcedony, barite, kaolinite, zeolites, calcite, pyrite; the secondary minerals are pyrolusite, limonite, calcite, and clays.

Fluorspar comprises 70 - 80 percent of the vein body and is represented by a large quantity of varieties, colored in green, violet, rose, yellow and other tones.

According to paragenetical relationships, it is possible to divide it into three generations. Fluorspar of the first generation

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is in close connection with the quartz and with the laminated barite, and forms symmetrical- or non-symmetrical-banded parts of the vein, deposited along the walls of the fractures. The banded structure of it is dependent on, on the one hand, the alternation of the fluorspar bands with the quartz, and on the other hand, the fluorspar itself inside these bands is built up of roughly parallel bands of different color -- violet and green of various shadings, smoke-colored or almost colorless bands, alternating with one another.

Any uniformity in the alternation of bands of one or another shading is not observed. The deposit from the walls of the fracture or from the quartzitic formations usually begins with violet or green fluorspar (more often with violet), but later one color could be repeated more often, the others more rarely and vice versa. The width of the band of one color is from 0.5 centimeter to 2 - 3 centimeters. The structure of the banded fluorspar is compact-crystalline; under the microscope, no difference between the differently colored bands is observed. During the deposit of the fluorspar of this generation, druses are formed in the cavities of octahedral crystals, usually covered by a crust of short-prismatic rock crystal. It is colored in those same colors as the banded fluorspar, and in one crystal a zonality of color is often observed, oriented parallelly to one of the facets of the crystal.

The fluorspar of the second generation is similar to that described and is connected with it continuously; the formation of it here to a certain degree is conditional, at least for the upper horizons of the main vein. In the lower horizons of it and in the Sakhalin vein it is formed more clearly, being separated from the

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first by the formation of a large quantity of laminated barite.
It is those same banded formations, which alternate with the quartz,

Figure 8. Microstructure of pseudomorphic fluorspar.
The black is pyrolusite, quartz and calcite. X 8
magnification.

but at the end of this phase a large role is acquired by the weakly colored varieties of fluorspar, which form, in places, concentric cockades with a weakly expressed columnar structure and which are crystallized chiefly in cubes, the druses of which often cover the walls of the cavities. To this same generation pertain the pseudomorphoses of fluorspar in the laminated barite, which is encountered often in mine No. 3 in the Sakhalin vein and discovered by drill holes in the center of the main vein. It is also violet and green fluorspar, usually of weak color, having the form of joining, laminated, fan-shaped clusters, bent and oriented in various directions (Figure 8). A comb-like character is given to the fluorspar by the presence in it of numerous, leaf-like cavities, collected in clusters, filled with quartz, pyrolusite and secondary calcite, although the fluorspar itself has a compact structure. These pseudomorphic forms are very close to the pseudomorphoses of the laminated quartz described below, extremely common for the fluorspar deposits of the Tyuringensk forest. In time of formation, the fluorspar pseudomorphoses are simultaneous or somewhat later than the leaf-like quartz.

Fluorspar of the third generation (the last) forms pseudomorphic crusts in the rhombohedral barite and a small-grained aggregate

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together with kaolin in the cavities of the vein. It is distinguished rather sharply from fluorspar of the first generation by the external form and several properties. In the crusts it is of columnar structure; often it produces a divergent concretion of a honey-yellow color. On the surface of the crusts the hexahedrons terminate with the facets of a cube. The thickness of the crusts is 1 centimeter, rarely any thicker. The kaolin-fluorspar aggregate is described above, in the characteristics of kaolin. The fluorspar here is colorless, in the form of small isometric grains; in size they are one-thousandth of a millimeter, sometimes even less. Into these grains are incorporated vermicular concretions and lamellas of kaolin. The differences in the properties of the fluorspar are expressed in the dissimilar behavior during heating. Thus, the fluorspar of the first generation during heating clearly fluoresces and is disintegrated; the columnar fluorspar of the last generation fluoresces very weakly and is not disintegrated from the heating. In this respect, this variety displays a complete similarity to the Kalanguy columnar fluorspar, which possesses those same properties. In regard to its chemical composition, the yellow fluorspar of Abagaytuy does not display any peculiarities. Data of the analysis (in percent) is given below:

Ca.....	50.29
BaSO ₄	None
F.....	48.71
S.....	None
P ₂ O ₅	None
CO ₂	None
SiO ₂	0.13

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Fe_2O_3 0.03
 Al_2O_3 0.17
 Loss during calcination..... 0.34

Minerals of the silicic acid group in the form of different varieties of quartz and chalcedony occupy first place after fluorspar according to degree of occurrence in the main and Sakhalin veins, and in the small veins they play the predominating role. The formation of them began earlier than the fluorspar and continued almost to the end of the process of vein-formation. The main mass of it crystallized, however, together with the fluorspar of the first and partially of the second generation.

The deposit of silicic acid in the vein took place rhythmically, repeatedly alternating with the fluorspar. The first portions of silicic acid, which form the cement of the breccia and fringe along the vein, were precipitated in the form of hornstone quartz and chalcedony, frequently with meta-colloidal, collo-morphic, fine banding. Only at the end, in the cavities of the breccia, was it crystallized in the form of comb-shaped or prismatic quartz. In the main phase of vein formation, the silicic acid produced, basically, small-grained, white, mosaic quartz, with rapid transitions, in the limits of one section, into comb-shaped or prismatic quartz, on the one hand, and into cryptocrystalline variety, on the other hand. It forms among the banded fluorspar roughly parallel bands varying in thickness from several millimeters to 0.30 meter. Besides this, the quartz forms microscopic veinlets in the fluorspar, small crusts of prismatic crystals on the druses of the former, in the cavities, etc. The crustified deposit of quartz is accompanied by processes of their

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replacing the earlier minerals, among them fluorspar, too. During the replacement of fluorspar by quartz, the latter often is precipitated in interesting forms -- in the form of rhomboid grains, little stars and little mushrooms. These forms completely are bound by convenient, easily available means for the penetration of silicic acid and replacement, namely, to the fractures of the cleavage, the points of intersection of the two directions of the fractures, etc.

As a consequence of the indicated interrelationship, the quartz and the fluorspar are closely connected with each other; however, inasmuch as the basic quantity of quartz is kept separate in more or less significant independent bands and streaks, in the process of extraction it is rather easily separated from the fluorspar, and, owing to this, the mine has the possibility of obtaining a high-quality product by means of primitive manual concentration.

Formations of laminated pseudomorphic quartz, which is encountered both in the main vein and also in the Sakhalin vein, in particular, are similar to the ore veins of the epithermal type, described by many authors. In particular, in the works of F. C. Shreder [106] and A. Knopf [101] photographs are provided, completely identical to ours, the first of the Tarbige veins, the second of the Belmont mine.

This variety of quartz represents leaves of a thickness sometimes less than the leaf of a book, collected into fan-shaped clusters up to 10 centimeters in length, which interlock with a compact end into the fluorspar, most often of all along the fractures of its cleavage. Under the microscope, the leaves consist of an aggregate

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of flattened grains, densely pressed one to the other. Each leaf usually is separated from the other by a fine film of brown manganese and ferrous oxide. The intervals between the leaf-like clusters either are occupied completely by quartz and fluorspar together or by one of them or are filled partially, forming in such a case irregular, polygonal cavities -- compartments, covered on the walls by brushes of prismatic quartz of zonal structure. Several authors consider similar empty compartments as places of leached calcite. In our case, these compartments, undoubtedly, belonged to the fluorspar, which, with the laminated mineral having taken root in it, was dissected into these polygonal blocks, and subsequently was replaced partially by quartz, but partially, evidently, was leached out. In many cases, however, it was preserved entirely or partially.

Figure 9. Laminated calcite (dark gray) among the quartz (light gray). X 40 magnification.

The authors indicated above consider these forms with the pseudomorphoses in the calcite, although they do not cite clear proofs of this. From the findings in the Sakhalin vein of the Abagaytuy deposit it follows that the laminated quartz in the given case represents soonest of all pseudomorphoses in the barite, and its laminated structure is dependent on the lamination of the latter. Here, Engineer Belovyy found, during operations, and obligingly transmitted to us, a sample of barite, on which it is not difficult to represent the mechanism of formation of laminated quartz. The sample represents a druse of laminated crystals of

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barite, the thickness of the laminas varying from several millimeters to a part of a millimeter coalesce into concretions of fan-shaped form, completely identical to the clusters of laminated quartz. In this sample, it is seen that the neighboring laminas, apparently, as a consequence of their different orientation, yield differently to the process of lixiviation. Owing to this, the surface, perpendicular to the surfaces of coalescence, has the form of a comb -- one of the lamina deeply leached out and the adjacent ones project with teeth. Evidently, in this way, the cavities which were leached out in their time, were occupied by quartz, as a consequence of the laminated nature of the cavities themselves, which assume a similar form. The remaining laminas of barite were leached out then, also, and their place was filled either by quartz or by secondary minerals -- pyrolusite and calcite.

Calcite is present in small quantity. Most interesting is the calcite detected under the microscope in samples from the yields of mine No. 3, together with the laminated quartz. Here, it forms laminated formations, which are stretched out parallelly to the basic pinacoid (Figure 9). They are located either between the laminas of quartz or in the middle of the quartzitic-fluorspar aggregate, always in close connection with the manganese oxides. In the latter case, the laminas, in cross section, have a form that is nearly needle-shaped. During observations of the interrelations with laminated quartz, the calcite often seem later than the quartz.

Besides this variety, in the walls of the vein, among the porphyritic breccia, veinlets of white calcite of compact-crystalline structure are encountered, with twin bands, which is characteristic

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of it. In them, it is found usually in paragenesis with quartz, fluorspar and pyrite, and is precipitated out by the latter.

Barite, as already noted above, is encountered sporadically at the present in the Abagaytuy deposit, but in the process of vein formation, undoubtedly, it played a large role. It is encountered in two generations. To the first generation pertains the laminated varieties, which were precipitated out after the first portions of fluorspar and quartz, but later replaced by them. Findings of barite of this variety are exceptionally rare. In the main vein, up to now, it has not been located anywhere, and it is possible to pass judgment on it according to the pseudomorphoses described above. In the veins of the Northern section, especially in the Sakhalin, it is come across more often. Inasmuch as the druses are always strongly leached out from the surface, the facets on them are indeterminate. In individual cases only is it possible to determine the facets (001). Barite of this variety is of a slightly yellowish color, semitransparent.

Barite of the second generation pertains to the date of the last vein minerals, which were precipitated out after the main mass of fluorspar and quartz on the walls of the cavities in the center of the vein. A considerable part of it also was leached out, and its place filled by a kaolin-fluorspar aggregate. But owing to this fact, that the columnar fluorspar which followed after it formed on it well-preserved pseudomorphic coatings, its presence is recognized easily by the unusual structure, argillo- and kaolin-fluorspar aggregate (Figure 10) and by remains of it within the indicated aggregate. Here, the barite is yellowish, bluish and whitish and forms concretions of rhombic crystals with facets (100),

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(001) and (010) ranging in size from very small to 15 centimeters on the edge. From time to time, it is encountered also in the form of rectangular prisms.

According to the report of P. P. Pilipenko, barite is encountered also in the cement of the breccia of granite near one of the northern veins, together with quartz and fluorspar.

Kaolin at Abagaytuy is widespread, accumulating in a large quantity in the southern part of the main vein. Paragenetically, it is closely connected with the last generation of fluorspar and with various argillaceous products of the disintegration of the wall rocks, filling, together with them, the cavities in the middle of the vein and forming deposits up to 2 meters in thickness and 10 meters in length. The basic mass of it is coordinated to the so-called porcelain-like kaolin-fluorspar aggregate, which macroscopically represents a white or grayish-white, compact rock, with component parts which are indistinguishable to the naked eye. The structure of this aggregate is diverse -- more often finely-banded, more rarely compact or breccia-like. In the rock there are usually many small, deep, sinuous pores, within which the fluorspar sometimes produces facets of cubes, with the surface covered by white, soft kaolin. Among the compact varieties, the mealy, quick varieties also are encountered. Under the microscope it is seen that the rock consists of kaolin, fluorspar and a small quantity of spindle-shaped grains of quartz, with a highly variable quantitative relation between the first two. In the majority of cases, the basic mass is comprised of fluorspar of fine-grained structure. In it is included kaolin in the form of lamellas, 0.002 - 0.005 millimeter in size, and

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vermicular concretions of them with sizes up to 0.01 millimeter. The variety of structure of this aggregate depends on the distribution of kaolin in it. The latter is extremely irregular and diverse. Sometimes the lamellas and concretions

Figure 10. Pseudomorphic crusts of fluorspar (black) in barite amongst kaolin. $\frac{1}{4}$ natural size.

float in the fluorspar, at others they accumulate in parallel bands, separated by bands of more or less pure fluorspar; sometimes they produce structures which are similar to ripple marks, or else assume a breccia-like appearance, where accumulations of kaolin play the role of the fragments. In samples with compact structure, an unbroken field of small lamellas of kaolin and the presence of cemented fluorspar is determined only by individual clearer "windows" and by chemical analyses. Amongst this aggregate now and again acute-angled fragments of barite and fluorspar of the first generations are encountered.

Quick varieties consist of those same components, differing from the compact by a large content of quartz at the time of the decrease of fluorspar, and represent, evidently, the product of the disintegration of the compact aggregate.

Chemical analyses (Table 3) of this aggregate show a high content in it of CaF_2 , especially in the compact varieties, completely sufficient for its utilization as flux. Up to this time at the mine, it was discarded into the dump; for the future the ore administration should consider the realization of it.

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If CaF_2 is excluded from the composition of the rock and the remainder is converted into kaolin, then the quantity of SiO_2 will be somewhat lower than for typical kaolins, which is expressed in the ratio $\text{SiO}_2 : \text{Al}_2\text{O}_3$ as 1.7 : 1; 1.4 : 1. Ross and Kerr [105] are inclined to explain such phenomena by "atomic isomorphism" -

Table 3

	Close-grained Variety, per cent	Close-grained Variety, per cent	Quick Var- iety, per cent
SiO_2	8.33	6.57	15.16
Al_2O_3	8.23	7.48	18.17
Fe_2O_3	0.07	0.02	0.08
FeO	None	-	-
MgO	0.13	-	-
CaO	56.80	58.23	-
F	38.50	39.60	-
K_2O	None	-	-
Na_2O	None	-	-
CO_2	-	None	-
BaSO_4	-	None	None
H_2O	0.37	-	-
$\text{H}_2\text{O} +$	3.17	4.59	-
	99.37	99.87	-
CaF_2	79.09	81.21	53.64

In conversion by F
 Determined
 analytically

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the capacity of silice and alumina to replace one another. In any case, the admixtures of any other minerals, rich in aluminum oxide, has not been determined by us. Optically, kaolin is characterized by weak double refraction, of the order 0,004 - 0,006, oblique extinction with a small angle and a positive elongation of the lamellas. According to the curve of heating (Figure 11) it is determined as "dikit" according to the nomenclature of Ross and Kerr, with an endothermic maximum of nearly 630 degrees. According to the conditions of its occurrence, this kaolin-fluorspar aggregate appears to be a secondary formation, deposited by descending waters after the termination of the basix process of mineralization. However, it is established, by works of the authors indicated above, that "dikit" is a hydrothermal mineral, which is not formed during the processes of disintegration. At the same time, the possibility of the presence in the descending ground waters of such large quantities of fluorine compounds provokes great doubts. Undoubtedly, the fluorspar under the action of atmospheric agents partially is dissolved. The constantly observed traces of leached out crystals in quartz speak for this, pseudomorphoses in it of minerals of the zone of disintegration, as limonite and t. p. facts. But all these phenomena have extremely limited rates, and signs of any serious solution of it which can give the source for such a quantity of a secondary product, as also of the phenomena themselves of a definite re-deposit by descending waters, we did not observe at any deposit. This circumstance compels us to consider the fluorspar of this generation with the deposit of the rising, warm waters, kaolin material, undoubtedly, was derived from the wall rocks, appar-

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ently with the aid of sulfuric acid solutions, which circulated in the vein zone in the process of leaching out of barite.

Argillaceous products of the disintegration of the wall rocks fill the fractures and cavities in the veins. They are represented by brownish, yellowish and light-gray varieties. The light-gray varieties play the largest role, occupying the place of the leached out barite - - pseudomorphic bands of it under the fluorspar crusts, and cementing these crusts in the cavities of the vein. Under the microscope, they consist of extremely fine laminated micaceous mineral with high double refraction and gray, amorphous mass, non-polarizing, kaolin-like. Like segregations of kaolin, this argillaceous mass is cut through by veinlets and is impregnated to the core by fluorspar, as a result of which rather hard rocks were formed.

Figure 11. Curve of the dessication of kaolin with a breccia-like structure, where lumps of clay play the role of the fragments. An analysis of this mass (in percent) also shows its kaolin composition and high content of CaF_2 .

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CaF ₂	67.80
SiO ₂	14.53
Al ₂ O ₃	8.30
Fe ₂ O ₃	0.66
FeO	None
MgO	0.98
Na ₂ O	None
K ₂ O	"
CO ₂	"
H ₂ O	3.89
H ₂ O †	3.17

 99.27

Zeolites are found in one of the small veins of the northern section. They join together with the small-grained quartz in the middle part of the vein, comprising in places up to 50 percent of the rock. They form irregular, sometimes flat, grains up to 0.2 millimeters in size, rarely larger, which are irregularly joined with hornstone quartz. Under the microscope it is seen the banded structure of the rock, with an alternation of the bands, rich in zeolites, with bands, chiefly with quartz or pure quartz. In the small cavities in the middle of the quartz-zeolitic aggregate, the zeolites form small crystals also in the form of tetrahedral, inclined prisms. The zeolite is of rosy color; under the microscope in the flat grains a well-expressed cleavage appears. It is optically positive, biaxial; $N_g = 1.524$, $N_p = 1.516$, $N_g - N_p = 0.008$, the elongation (in relation to the fractures of the

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cleavage) is negative the fading is nearly 10 degrees. In hydrochloric acid it is dissolved without the precipitation of the substance. In its properties it most nearly of all approaches thomonite.

Pyrite is present in the changed wall rocks in the form of diffused phenocrysts.

Pyrolusite is a brownish-black ore mineral, coordinated to the leaf-like pseudomorphoses of fluorspar and quartz. The streak is black, it is dull or with a metallic finish, with a blow torch it produces a reaction to manganese; it does not contain water. In the laminated aggregate of the indicated minerals, it forms a leaf-like formation of up to 0.5 millimeter in thickness, which is interstratified with laminae of fluorspar and quartz. Together with manganese and ferrous hydroxides, it is present also amongst the laminated calcite. The constant close connection of pyrolusite with the laminated pseudomorphoses leads to the thought that it represents the product of the leaching out of the primary laminated mineral, in which, apparently, the manganese was contained in a rather large quantity.

Manganese hydroxides (manganite) occupy a position similar to the pyrolusite, being encountered usually in the surface parts of the vein, also along the edges of the pyrolusite formations, representing the product of their change.

Secondary calcite forms crusts in the fractures and cavities in the veins, on the whole being present in insignificant quantity.

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Changes of the Wall Rocks

Changes of the wall rocks are expressed almost equally both in the upper side and also in the under side; they occupy a comparatively narrow strip of 1 - 2 meters. They lead to sericitization, chloritization, pyritization and silicification.

Sericitization embraces the feldspar part of the porphyrites, which, near the vein, are replaced by sericite and chalcedony almost entirely. The structure of the rock thereby usually is all preserved.

Chloritization and carbonization are not specifically for contacts, developing extremely widely in all sections of the deposit. It follows only to note the appearance in individual cases of little cords and radial aggregates of chloritic lamines among the cherty breccia.

Pyritization is peculiar to both walls of the vein equally. Pyrite in the form of cube-shaped blocks and irregular grains form phenocrysts amongst the silicified porphyrite.

The occurrences of silicification represent the most clearly express contract process. Silicification is connected both with the formation of silicic acid during the decomposition of silicates and also with the introduction of it. Silicic acid in the form of chalcedony and cherty quartz cements the breccia of the porphyrite and simultaneously replaces it. The latter, however, is considerably more weakly developed than in certain

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certain other deposits, as, for example, at Takob.

The fluoritization of the casings is expressed in the presence of veinlets of fluorspar amongst the breccia, together with the silicic acid, whereas the fluorspar always follows after the quartz, occupying the middle of the veinlets.

Fragments of wall rocks, which are enclosed in the vein, undergo those same changes, the only difference being that, as a rule, they are highly silicified, being replaced by it almost entirely in small fragments.

The characteristics of the structure of the vein brought out above, as the symmetrical-banded, crustified structure, the presence of cavities etc., characterize the Abagaytuy deposit as a fracture fulfillment of small depth.

In contrast to the Kalanguy and Solonech deposits, the mineral solutions here were of composite composition, in which, in addition to the silicide and fluorine compounds, sulfuric acid compounds and, perhaps, carbonic acid were present. In the paragenetical relationships of the vein components, described in the accompanying table (Figure 12), for the Main and Sakhalin veins, it is possible to contemplate several successive phases of mineralization. In the first phase, there were silicic-fluorine solutions, which precipitated quartz and fluorspar with a rhythmic interchange of the one by the other, owing to which the banded structures were formed. Later on, the solutions were enriched with fulfates and the precipitation of the laminated barite takes place. This phase in the upper parts of the main

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vein developed a weak reflection, having developed considerably more intensively in the Sakhalin vein and in the deep horizons of the main vein. The second vigorous silicic-fluorine phase followed after this. Here, the silicic acid and CaF_2 were crystallized also, rhythmically, but the basic mass of the first was precipitated in the beginning of the phase, then, as at the end of it, fluorspar was formed, almost free of quartz. Into this phase the earlier precipitated barite was dissolved almost entirely and replaced by quartz and fluorspar; then the solutions noticeably became impoverished by silicic acid and fluorine compounds, yielding the place again to the sulfuric acid solutions.

The role of the latter here was limited by the deposit of barite in the remaining cavities, which is why the barite of this generation in the structure of the vein on the whole occupies a small place. The final stage of mineralization again is characterized by the deposit of fluorspar, but, in contrast to the former, it is connected already, not with the quartz, but with the kaolin. This stage led to the formation of pseudomorphic crusts of columnar fluorspar in the barite and kaolin-fluorspar, fine-grained aggregate in the center of the vein. The filling up of the vein, evidently, took place in conditions of gradually reduced temperature within the limits of approximately 300 degrees to 150 degrees and, probably, lower.

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Minerals	Stages of Mineralization	
	Beginning	Final
Quartz and Chalcedony	(111)	(110) columnar columnar
Fluorspar		laminated
Barite		
Kaolin		
Pyrolusite		
Pyrite		

Figure 12. Table of sequence of formation of minerals for the Main and Sakhalin veins.

SOLONECH DEPOSIT

Structure and Composition

The Solonech deposit represents a typical complex, steeply dipping vein, with branching sections and numerous wall veinlets. It occurs in biotitic-hornblende granites, being coordinated to a broad zone of tectonic disintegration.

The processes of mineralization here developed in huge sizes; the thickness of the complex vein in its average part reaches up to 2 - 4 meters.

The composition of the deposit is uniform and poor. Be-

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sides the fluorspar, quartz, chalcedony and adular participate in the structure of the vein; the first two comprise nearly 99 per cent of the vein mass.

The process of their deposit is sharply divided into two stages. The first of them is characterized by a predominance in the solutions of fluorine compounds, leading to the filling up of all the fracture zone with pure fluorspar. The second stage of mineralization followed after a certain break, during which time the original fluorspar filling was once again shattered, with the formation of breccia. This stage produced adular and quartz, which occupied the role of a cement in the shattered fluorspar. Inasmuch as, however, the repeated exposure of the fracture occurred along the under side of the vein, the large part of quartz here also are concentrated in the form of an almost pure quartz here also are concentrated in the form of an almost pure quartz zone 4 - 10 meters thick, being in lesser degree directly connected with the fluorspar. The zone of unbroken quartz in the quartzitic-fluorspar part of the vein passes over more or less gradually; at the beginning among the quartz infrequent fragments of fluorspar appear. Later, the amount of fluorspar increases and then begins to predominate, but the quartz remains in the form of fine veinlets.

Crystallization of fluorspar again took place in the final stage of mineralization, after chalcedony, but in completely insignificant sizes and, possibly, from descending waters. Here it was deposited in the cavities of the breccia, but most often of all on the crusts of the chalcedony.

Thus, for Solonech, the formation of fluorspar prior to

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the main phase of formation of silicic acid is characteristic. Silicification of the casings of the veins, which preceded the deposit of vein minerals, is widely developed in the deposit, but it occurred basically, evidently, because of the silica of the granites themselves during the insignificant introduction, or even entirely without its introduction, by hydrothermal actions.

Description of the Minerals

Fluorspar in the deposit is almost entirely represented by a formation of the first generation. It possesses a uniform form and is distinguished from the fluorspar of other deposits by a more intensive rich color, less transparency, almost with a complete absence of any inclusions, and, as a result of this, with great purity. Its structure is close-grained, crystalline. Columnar formations, like the ribbon and banded structures, are completely absent.

Figure 13. Breccia of Fluorspar (dark) with quartz cement.

Natural size.

The color is violet and green of various shadings, sometimes almost colorless. These colors in the mass of fluorspar are distributed without any apparent uniformity; it is noted only that the coloring of the casings are chiefly in rich, dark tones. In the large fragments, the fluorspar is not clear; in the fine fragments even the dark-colored varieties are translucent. At a temperature of 225 degrees, the fluorspar gleams with a violet color, is split easily and discolors. Since the

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fluorspar of the describer generation was precipitated out separately from the other vein components, it is completely free of inclusions and is very pure. The presence of inclusions of fragments of wall rocks in the mass of fluorspar also does not upset the impression of its exceptional purity, inasmuch as the fragments usually are of rather large sizes (rarely less than 0.5 centimeter) and owing to the absence of the occurrence of its replacement by fluorspar, is separated from it sharply.

Figure 14. Crusts of comb-like quartz, Natural size,
a - fluorspar; b - quartz.

The numerous branched network of veinlets of quartz and adular divide the fluorspar into small pieces. Fragments of it usually have acute-angled forms (Figure 13), which are bound by rectilinear sides, usually corresponding with the direction of the fractures of the cleavage. Directly on the surface of the fluorspar fragments most often of all is located a thin layer, 0.05 - 1.0 millimeter, of small-grained adular. The fine fractures sometimes are filled with it entirely. On the layer of adular or directly onto the fluorspar in the absence of the former is deposited the quartz. The occurrence of replacement of the fluorspar by these minerals has not been observed - deposits of them as if applied to the flat faces of the fragments. Owing to this the cementing minerals very easily and almost without a residue are separated out from the fluorspar. Such a character of their interrelationship has a very important significance, inasmuch as it guarantees the ease of enrichment of the ore, which, in the absence of foreign substances within the individual fragments of fluorspar,

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in essence leads to the separating out of the adular-quartzitic cement of the breccia.

The second generation of fluorspar was precipitated after the quartz and chalcedony, and forms on them crusts and in the cavities individual crystals or concretions of crystals in the form of cubes up to 2 centimeters on the edge. They usually are colored in pale violets, more rarely in greenish tones. In its quantity, the fluorspar of this generation has only mineralogical interest.

Quartz in quantity in the deposit occupies approximately an equal place with the fluorspar; its main mass is concentrated in the under side of the vein. The quartz, cementing the breccia of fluorspar and dissecting it with veinlets, is represented by a long prismatic, often even up to needle-shaped, comb-shaped variety, frequently forming radial concretions around the fragments of fluorspar (Figure 14). The comb-like formations, at the same time, possess excellent feather structures. In the narrow fractures and in the unbroken masses, the quartz passes over into an aggregate of irregular, very unequal grains. Together with this, but in lesser quantity, hornstone quartz also is encountered, on the walls of the fractures passing over into short prismatic variety. Amongst the long prismatic variety, under the microscope two generations are detected, which are inclusions one in the other. In the quartz there are always many dust-like mineral inclusions.

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Minerals	Phases		
	Beginning	Middle	Final
Fluorspar			
Adular			
Quartz			
Chalcedony			

Brecciation

Figure 15. Table of the sequence of formation of the minerals

Chalcedony follows after the comb-like quartz, having been deposited on the surface of its crusts in the cavities of breccia in the form of thinly-laminated dense masses, and partially penetrates into the intervals between the separate comb-like crystals. A large quantity of flaky, brown mineral inclusion is present in it. Both varieties of silicic acid from the surface and in the fractures are covered by a deposit of brown ferrous oxides.

Adular is present in small quantity, and, as was related above, covers the surface of the fluorspar fragments with a film, penetrates into the fine fractures together with the quartz etc. Macroscopically, it forms a white, compact, sometimes semi-powdered, mass. Under the microscope is seen the composition of small, irregular, more rarely flat grains, which are characterized by low double refraction: $N_g - N_p = 0.006 - 0.008$; indicators of refraction are characteristic for orthoclase. In the flat grains is disclosed a clearly expressed cleavage in one direction. It is optically biaxial, with a large angle of 2ϵ , positive. It does

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not dissolve in hydrochloric acid. The deposit of it took place earlier than the main mass of quartz, but partially simultaneously with it.

Arillaceous products in the vein body are present in small quantity, filling up the fractures and cavities among the breccia and are represented by common brown clay.

The sequence of formation of the minerals is represented in Table 15 above.

Changes of the Wall Rocks

In the Solonech deposit the enclosing rocks in the walls of the vein bear traces of metasomatic changes, incomparably more sharply and widely developed than at the other deposits described. The band of changed rocks reaches a width of 50-60 meters on each side of the vein, and macroscopically is expressed in the purification of the rocks. In character, these changes represent basically, also hydrothermal metasomatism, in which, during microscopic study, several successive stages are distinguished.

In the granites originally occurs the partial sericitization of the plagioclases and simultaneously with it the partial chloritization and epidotization of the dark-colored minerals. These occurrences are observed both at considerable distance from the vein and also 5 - 6 meters from it, being distinguished only by the degree of development.

Nearer to the vein, but sometimes as far as 10 - 12 meters from it, the plagioclase part of the rock is sericitized

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almost entirely. The potash feldspars in this stage are still preserved almost completely fresh.

The next and last stage is expressed in the complete disappearance from the granites of the feldspars and the dark-colored minerals. The former are replaced by an aggregate of fine-grained secondary quartz and sericite; the biotite is entirely replaced by muscovite. Of the hornblende, only epidote and saenite remain. As a result of this, the granite in direct proximity to the vein and in fragments within it loses its structure; it consists of separate grains of primary quartz, cemented by a quartzitic-sericitic secondary product. The quartz is the most stable, but it, also, along the edges of the grains usually is replaced by secondary quartz with sericite. Together with this, in the final product of change, it is a noticeably increased content of apatite in the form of small scales and prisms. In the porphyrites, metasomatism is uniform and is expressed somewhat more weakly. In them, it results in the complete sericitization of the plagioclases, but its structure is usually more or less preserved.

In addition to the enumerated occurrences, the rocks at the contacts were pyritized. Pyrite itself was preserved only in the porphyrites, rarely in the granites, but regarding its constant presence in the latter, it is possible to judge according to the limonite in the form of cubical crystals, which are, evidently, pseudomorphoses in pyrite. Frequently, the limonite is entirely leached out, and only cavities of square cross section with brown borders were preserved.

Kaolinization does not play any role, developing in the

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turbidity of the feldspar, which is characteristic of the region generally.

Fluoritization is expressed in the filling up of the fractures of shattering in the rocks. Sometimes it produces an impregnation in the granite, penetrating with individual small round grains into the secondary quartzitic-sericitic aggregate; however, these occurrences are completely insignificant in their scale.

Chemical changes, similar to those of Kalanguy, as seen from the enclosed analyses (Table 6), are expressed in the loss of Fe, Al, Ca, Na, concentrations of SiO_2 and K and in hydration. In analysis No. 3 note the high content of P_2O_5 (Table 4).

In the samples of changed granite, the quantity of apatite also seems to be abnormally high. Undoubtedly, a considerable part of it represents the remaining material of granite, but at the same time it does not exclude the possibility of a neogene of it in connection with contact action.

Secondary Changes

Inasmuch as the deposits of Trans-Baikalia are composed of minerals which are extremely stable in the zone of disintegration, secondary changes do not produce any noticeable development.

Of such at the time of the examination of the deposit, the mechanical disintegration of the fluorspar itself, first of all, is conspicuous. The ends of the veins in the outcroppings usually were highly fractured and shattered into small fragments. The

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latter, close to the outcroppings, usually form a talus, in which also is disclosed again a majority of exposed deposits.

Table 4¹

	I	II	III
	Normal Granite	Changed Granite, 12 meters from Vein, Upper side	Changed Granite, 0.5 meter from Vein, Upper side
SiO ₂	68.36	79.10	71.08
TiO ₂	0.30	0.28	—
Al ₂ O ₃	13.56	11.21	10.18
CaF ₂	—	—	8.31
Fe ₂ O ₃	1.47	0.41	0.36
FeO	1.63	0.28	0.29
MgO	2.40	0.48	0.68
CaO	2.81	0.49	0.80
Na ₂ O	3.84	0.25	0.15
K ₂ O	3.90	5.67	5.42
P ₂ O ₅	—	—	0.74
H ₂ O —	0.76	0.59	0.44
Loss during Calcination	0.40	1.75	—
	99.43	100.53	98.45

(¹ The analyses were carried out in the Central Analytical Laboratory of the IMS by Analyst N. Voronkova.)

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Especially strongly subjected to shattering are the columnar varieties of fluorspar, evidently, as a consequence of the peculiarity of their structure and the absence of quartz. In the upper parts of the veins of the deposits at Kalanguy and Taminga, it is converted into gravel and even sands. Cockades, completely whole in form, disintegrated into small fragments upon being struck with a hammer.

Problems of the chemical disintegration of fluorspar and its re-deposit by surface waters have been insufficiently studied.

It is known that at customary temperature in water it dissolves very slightly (18 milligram/liters); in the presence of carbon dioxide the solubility somewhat increases.

Judging by available data, the leaching out of it by surface waters, undoubtedly, takes place, but on a very slight scale. The empty compartments in the quartz in place of crystals of fluorspar, which are observed in the outcroppings of many veins, the smooth angles of the crystals etc., serve as evidence of this.

Del'ter [97] cites indications concerning the findings of pseudomorphoses of minerals of oxidized zone -- limonite, cerussite, pyrolusite and other minerals in the fluorspar.

Above we made reference to the findings at Kalanguy of a formation of secondary fluorspar in the form of typical stalactites. But there P. P. Pilipenko, in his report, observed small cubes of fluorspar, which were formed simultaneously with nontronite. At the Solonech deposit, fluorspar at the second generation, forming

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individual small cubes on the crusts of chalcedony, also exceedingly suggests a secondary formation. At the Abagaytuy deposit, the fine-grained fluorspar, impregnating the kaolinite mass in the center of the vein, like the pseudomorphic crusts in barite, according to the conditions of occurrence, also is extremely similar to a secondary formation. In the given case, the relationship of this fluorspar to the secondary product is confused only by the fact that indications are not found of the leaching out of such quantities, which would have provided the inflow of a large mass of secondary product. Deposits of kaolin-fluorspar here often have a thickness of 1.5 - 2 meters, sometimes up to 5 meters, and there is no doubt that in 70 per cent of the content in it the CaF_2 required a solution in huge quantities, which was not observed. The secondary fluorspar for the Boguchan deposit is pointed out by Rentgarten [2], where it forms crusts and deposits on the walls of the fractures and cavities.

In this manner, evidently, the secondary changes of the fluorspar itself lead to a very insignificant diffusion of it and re-deposit.

Of other occurrences of a superficial nature the deposit of ferrous oxide, calcite, chalcedony and opal in the fractures and cavities in the veins out to be noted.

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RESTRICTEDGENESIS OF THE FLUORSPAR DEPOSITS OF TRANS-BAIKALIA

A. V. Gulyayev

There are various theories of the genesis of the fluorspar deposits, which can be reduced to two.

Several investigators explain it by the action of the descending waters; the surrounding rocks served as the source of the vein material, from the former the appropriate elements by one means or another were drawn off, leached out, concentrated and then in the presence of favorable conditions were deposited. Theories of such a nature predominated in the 'Eighties of the last century, when they were applied to explain the occurrence of many fluorspar deposits by Norwood [97], Shaler [107], Emmons [98] for the deposits of Southern Illinois and Western Kentucky, by Hornung [99] for the Hartz deposits, and by others.

The opponents of this theory consider that fluorspar was formed under the influence of ascending agents, connected with the magmatic fires. The majority of contemporary investigators take this point of view. Together with this, ideas exist which reconcile both of these hypotheses. Thus, Ulrich and Smith refer the W. I. Tanger deposits of Western Kentucky to the deposits of hot, ascending waters, but accept the surrounding rocks as the source of the vein elements, among them, also, the fluorine.

At the present time, it is completely certain that fluorspar is capable of being formed in the most various conditions, beginning with the pneumatolytic, perhaps even the pegmatitic, stages of cooling off of the magmatic fire, up to the epithermal formations,

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together with the mercuric ores, and further in the sea basins. At the same time, with sufficient basis, one can say that all more or less large accumulations of it, which in fact can be called deposits, represent hydrothermal products. In this respect, the works of Wilson [110], Johnston [100], Currier [96], Staub [108], Chermette Sire [95], Smol'yaninova [54] and others should be noted, which yielded during recent years rather similar descriptions and classifications of the deposits for the entire field.

The deposits of Trans-Baikalia, which are being described, are not exceptions in this respect. Their general coordination to tectonic dislocations, vein occurrence, freedom from dependence on the nature of the enclosing rocks in simultaneous connection with acid, eruptive blocks repudiate, obviously, the hypotheses of their formation from descending waters and point to a plutonic occurrence. Analyses carried out by us, moreover, show the absence of fluorine in the surrounding rocks (determined in the sandstones of Kalanguy and in granites of Solonech deposit). On the other hand, the association of the vein minerals in the form of quartz, barite, adular etc., identifies the composition of the veins as a hydrothermal complex. In not one deposit is disclosed characteristic pneumatolytic minerals, not taking into consideration fluorspar itself as non-characteristic. Contact actions also bear the character of the ordinary hydrothermal metasomatism, being expressed mainly in sericitization, kaolinization and silicification.

As a consequence of the equality and slight characteristic quality of the vein components, a more detailed determination of the conditions of formation of the separate deposits encounters

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well-known difficulties. The more so it is confirmed, if the deposits are taken individually, outside of the connection of one with the other. In the first period of study of the Trans-Baikalia deposits this circumstance led several investigators to an erroneous conclusion regarding the pneumatolytic formation of the Kalanguy deposit. At the present time upwards of tens of deposits are being prospected and studied, and there is the possibility of comparing them with one another, which somewhat lightens the task. In the future we shall attempt to establish the inter-relationships of the chief deposits.

In light of the available material, the mono-mineral deposits of the Kalanguy type are represented by the lowest temperature formations of fluorspar among the Trans-Baikalia deposits; the Solonech type is represented by the highest temperature formations and the quartzitic-baritic-fluoritic type, such as Abagaytuy, is represented by intermediate formations.

From what has been said, it is seen that the Kalanguy deposit possesses several unique features, which distinguish it from the others. These peculiarities for the main vein of the deposit are:

1. The almost complete absence of typical vein minerals, in addition to fluorspar, the constant companion of it -- quartz, in particular. The latter, it is true, is present in the deposit, but in comparison to the other deposits, it is found in completely insignificant quantity exclusively in the surrounding breccia. In the vein body itself, with the exception of crusts of chalcedony and opal of "gipergenny" origin, to all intents and purposes it is

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not encountered. By the way, it should be noted, that the insignificance of the inflow of silicic acid before the fluorspar and, as a consequence of this, the extremely weak silicification of the wall rocks, played the determinate role in the further course of metasomatism. Precisely because of this, here there is a comparatively broadly developed replacement of the wall rocks by fluorspar. In those deposits where the fluorspar was preceded by the formation of a large mass of silica, the latter among the breccia filled up all the fractures and cavities and made the rock inaccessible to the fluorine compounds and hampered the interaction between them. Therefore, as a rule, intensive silicification excludes the occurrences of replacement of the wall rocks by fluorspar.

2. The second characteristic feature of this deposit is the predominating kaolin type of metasomatism of the surrounding rocks and the paragenetical connection of the fluorspar itself, besides in the first stage of its formation, with the kaolin, which is noted above.

3. So, the properties of the fluorspar itself are very characteristic and sharply conspicuous -- its columnar structure, the pale, weak colors and the concentric-shelly structures. Its close-grained, crystalline and large-grained varieties are rare here and usually coordinated to the casings of the vein.

Already a comparison of this deposit with the Abagaytuy deposit leads to the conclusion that the conditions of formation of the Kalanguy completely match the final stage of mineralization of the Abagaytuy deposit. In the latter, the concluding phase of

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formation of the vein is distinguished by those same features: quartz and chalcedony extremely abundant in the main stage of mineralization, toward the end decreasing and dwindling down almost to nothing; crystallization of the other components, like barite, also coming to an end. The fluorspar passes over from the start from close-grained into coarse-columnar, and then into fine columnar or fine-grained. As in the Kalanguy deposit, simultaneously with this, "large-crystalline" kaolin is separated out.

This conclusion is confirmed also by the other deposits, such as the Taminga, Ninth Friday etc.

The Taminga deposit consists of three small veins, located close together, which together combine the formations of the type of Kalanguy and the main phase of the Abagaytuy deposit. Here, vein Number 3 (III Taminga), in its mineralogical composition, paragenetical relationships and influence on the wall rocks is completely identical to the beginning phase of mineralization of the Abagaytuy deposit. Together with the fluorspar of close-grained structure, here there is present a great deal of hornstone quartz and comb-shaped quartz closely coalescing with the former. In that same paragenetical connection as in the Abagaytuy deposit also, traces of laminated barite (calcite?) are found in the form of pseudomorphic quartz and porous structures in the fluorspar. The filling up of the vein was preceded by intensive sericitization and silicification of the casings, whereas occurrences of kaolinization play almost no role.

Veins Number 1 and 2 in general are similar to the Kalanguy deposit; basically, they are built up by cockades of columnar

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fluorspar with the products of kaolinization. But together with that, here, in a small quantity but constantly present, are the large-grained, compact varieties of fluorspar of green or bluish-green color in close connection with the quartz. They usually are coordinated to the walls of the vein, most often of all to the upper side, joining the cement of the breccia, and, undoubtedly, were formed earlier than the columnar, quartz-free varieties, which occupy the central part of the vein body.

In the veins of the Ninth Friday deposit is observed a similar regularity -- the close-grained crystalline varieties of fluorspar are formed in the first phase, together with the abundant quartz and sporadic laminated barite, and in the second phase columnar fluorspar is formed, already without any accompanying minerals or with a single accompanying mineral -- kaolin.

These data show that the physico-chemical conditions of formation of the Kalanguy deposit completely match the conditions of the concluding stage of mineralization of the Abagaytuy deposit.

Judging by the changes in the composition of the veins of Abagaytuy, Ninth Friday and Taminga (with the sequence: quartz -- laminated barite -- quartz (or chalcedony) -- rhombohedral barite -- kaolin), the process of their formation took place in conditions of a drop in the temperature. Therefore, the Kalanguy deposit and those similar to it are referred naturally to the lowest temperature formations in a series of others.

It is considerably more difficult to draw a parallel between the Solonech deposit and the remainder. As is known, adular, quartz

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and chalcedony enter into its composition, in addition to the fluor-spar. In the given case, quartz may serve for comparison. In the Solonech deposit it is represented by elongated-columnar, comb-shaped and large-grained, semi-transparent white varieties in the insignificant role of hornstone-like and short-prismatic varieties. In the Abagaytuy deposit, on the contrary, the small-grained varieties predominate, frequently of the hornstone type or even chalcedony-like. Questions of the dependence of external form on the conditions of formation for quartz are still little studied; individual investigators frequently refer one and the same variety of it to formation in different temperature conditions. But the relationship of columnar, comb-shaped varieties to the small-grained and short-prismatic varieties is given more or less similarly by various authors -- the former precede the latter. As illustration, we cite the data of W. Maucher and A. Ye. Fersman [67] for hydrothermalites and pegmatites and N. N. Gornostayev for the Soviet deposit of gold.

Phases according to Fersman						
(1)	BCDE (2)	F—G (3)	H (4)	I (5)	K (6)	L (7)
According to Maucher	Smoke- colored	Gray	Dauphin Swiss Columnar	Chalcedony	Short- Prismatic Small Crystalline	

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(1)	(2)	(3)	(4)	(5)	(6)	(7)
According to		Milky	Dauphin	Small	Amethyst	Fine
Fersman		(some-	Columnar	Crystalline	Short	Crystals,
		times)			Columnar	Short
						Prismatic

According to	Smoky,	Semi-milky	Transparent	Chalcedony-
Gornostyayev	Milky,		Small-grained	like
	Coarse-			
	grained	Comb-like	Transparent	
			Fine-grained,	
		Finely-comb-	Fine-	
		like	columnar	

Together with this the effect on the enclosing rocks also shows in the more high temperature nature of the Solonech deposit in comparison with the Abagaytuy deposit. The nature of the latter in both deposits is one and the same -- basically sericitization and silicification, but sharply different in degree. In the Solonech deposit, the rocks are changed considerably deeper and over a wider area -- some tens of meters to the side of the vein, whereas in the Abagaytuy deposit the zone of contact change comprises not more than 2-3 meters. If in the Abagaytuy deposit, in addition to this, the porphyrites and granites more or less preserve their original structure, then in the Solonech deposit an almost complete change of the minerals of granite takes place with secondary products. It is certain that the degree of change of the walls of the vein depends on many factors -- on the nature of the rocks themselves, degree of their shatterability, composition of the solutions etc.; however, the effect of temperature

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must be taken into consideration also.

To what has been said should be added the fact that the high content of apatite in the changed granite of the Solonech deposit may be interpreted as an indication of the small participation in the beginning of the vein process and pneumatolytic phase, which we do not have at all in the Abagaytuy deposit. On the other hand, the low-temperature stage of mineralization, similar to Kalanguy, is completely absent in the Solonech deposit.

These considerations permit us to present the sequence of formation of the main Trans-Baikal deposits by means of the following chart (Figure 1), according to which the hydrothermal process of fluorspar formation for this region is divided into three stages: I is the highest temperature, silica-fluorine; II possesses a mixed composition of solutions, which led to the formation of veins of complex composition and where together with the silica-fluorines, the sulfates play a large role and, perhaps, carbon dioxide; in the final, the III stage, the formation of accompanying minerals ceases and it has mono-mineral, fluorspar formations.

	I	II	III
Solonech			
Urulyunguy			
Sedlov			
Abagaytuy			
Ninth Friday			
Taminga			
Kalanguy			
Kuranzha			

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	I	II	III
Fluorspar			
Quartz and Chalcedony			
Barite			
Adular			
Zeolite			
Kaolin			

According to the standard classification, these deposits should be referred to the epithermal and transition from the epithermal to the mesothermal. Industrially, they are the most favorable formations of the beginning and final stages, because they are the thickest, the fluorspar in them has a maximum concentration and the ore is of high quality. In the Kalanguy deposit, the large quantity of fragmental inclusions of wall rocks strongly deteriorates the quality, the fragments being scattered in the entire vein mass, besides being very small and hard to separate. The Solonech deposit possesses huge reserves and, owing to the formation of the fluorspar earlier than its companions, the ore is very easily concentrated. Deposits equal to the Solonech in size and quality have not been found as yet in the Union.

The question concerning the conditions of deposit of large accumulations of pure fluorspar is dealt with by Preihäusser [107]. This process he describes in the following manner.

Hydrogen fluoride, emerging from the magmatic furnace

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together with steam, upon encountering silicon dioxide or silicates passes over into SiF_4 . During the achievement by it of lower temperatures or during condensation, the steam of the water acted on the SiF_4 according to the formula $3\text{SiF}_4 - \text{nH}_2\text{O} \rightarrow 2\text{H}_2\text{SiF}_6 - \text{SiO}_2 \cdot \text{nH}_2\text{O}$.

The crystallization of the silicic acid on the walls of the fractures began and the solutions with H_2SiF_6 ascended further, and, upon encountering compounds of calcium, passed over into CaSiF_6 . Acquiring great specific gravity as a consequence of the cooling and rising of the CaSiF_6 , during fluctuation of the influx, the solution again descended in the fracture and at great depths, at high temperatures, separated into CaF_2 and SiF_4 . The crystallization of the CaF_2 took place, which later was not dissolved, owing to the presence of the ions F^- and SiF_6^{4-} , according to the law of masses. The liberated SiF_4 , under the action of water, again passed over into H_2SiF_6 and the process again was repeated. On the basis of these reactions, Preihäusser [104] notes the following types of deposits for the deposit of Oberfalz, which he studied:

- (1) the uppermost veins of purely quartzitic composition;
- (2) the middle veins of quartzitic-fluorspar composition
- (3) the deepest veins of fluorspar composition with barite and sulfides.

If, basically, this hypothesis is correct, yet it is impossible to agree with the conclusions of the author. In reality, in part of the quartz more rapidly it is necessary to wait for the reverse occurrence, because in conditions of influx of fresh material and decreasing temperatures the SiO_2 will be liberated by

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the first from the fluorine compound and will precipitate. According to the degree of removal from the magmatic source or diminution of the influx of material, the solutions on their way more and more lose their silicic acid and at the end deposit almost fluorspar alone.

Thus, the inter-relationships of SiO_2 and CaF_2 in the veins, evidently, depend, on the one hand, on the course which the solutions went through from the primary source, and on the other hand, on the influx of material. Therefore, with deepening, it follows to expect an increase in the quantity of quartz, especially for such deposits as the Kalanguy.

There is as yet very little factual material concerning the changes with depth, because the fluorspar deposits have been studied at slight depth (we have several of them down to 240 meters; in Germany, individual mines have been sunk to 500 meters, but there are no detailed descriptions). N. S. Lavrovich [317], for Kalanguy, on the basis of chemical analyses of samples, notes the diminution of the content of CaF_2 with depth because of the increase of SiO_2 . This is quite regular, but in the given case the figures cited by him are of little value with respect to geo-chemistry, because the basic mass of SiO_2 in the Kalanguy deposit belongs to the minerals of the wall rocks, included in the vein. For the Abagaytuy deposit, with the depth completely determined, the increase of laminated barite (calcite?) is marked during the disappearance of the kaolinized core. Inasmuch as the laminated material was almost completely replaced later by the fluorspar, there is no basis for fearing the impoverishment of the vein of fluorspar near the surface,

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but traces of this mineral undoubtedly deteriorates the quality of the ore. Judging by the analyses, the quantity of foreign substances in this pseudomorphic fluorspar is not more, and sometimes less, than in the ore which was extracted earlier, but as a consequence of the close coalescing of the admixtures with the fluorspar it is impossible to separate them by those primitive methods, with the aid of which up until recently the Abagaytuy deposit gave extremely high-quality products.

Data on the changes which take place with depth in the deposits of other countries is very scarce and brief. Judging by the indications of individual authors, brought out in the work of Medenback [102], an increase of quartz with depth is noted for the quartzitic-fluorspar deposits, whereas, in the deposits with a large amount of barite, the content of fluorspar increases with depth because of the diminution of barite, while sometimes, also, a simultaneous increase of quartz is shown.

Indications of the thinning out or decrease of thickness has not been observed in the depths which have been examined in any of the working deposits. Examples of rapid thinning out to the depth of thin, short veins is frequent, but this has already been explained by the behavior of the vein container. For such deposits as the Kalanguy, Solonech and Abagaytuy, where the length of the fracture zone reaches up to a kilometer, there is no basis for expecting a rapid decrease of its thickness with depth. Similarly, there is no basis for expecting a rapid disappearance of fluorspar, inasmuch as all these deposits have the character of a formation of little depth, but fluorspar is concentrated also

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at great depths in deposits of the mesothermal type.

The deposits of Trans-Baikalia are connected with the fractures of the type of faults, which have a local significance. Their trend is very diverse and no regularity has been established. For the majority of them a northeast trend is characteristic, however, and close to the meridional, conforming to the direction of the basic tectonic elements of the region; many veins, however, are of the latitudinal as well, with a northeast trend.

Fields of distribution of the young, post-jurassic acid intrusions (granites and granodiorites) are a factor which determines the geographical location of the deposits. The connection of the deposits with the latter emerges rather clearly. The veins occur both among these young granites and also among the various sedimentary and the more ancient eruptive rocks, the nature of which has no controlling significance, but they usually are located near the exposed edge of the granite blocks on both sides of the contact. The majority of known deposits are removed from it not more than 2 kilometers, usually closer, but in individual cases further (5 kilometers). Neither in the central parts of the granite blocks, nor in the sedimentary fields very remote from them, has there been stated a single fluorspar deposit. This regularity can be explained only by the genetical connection of the deposits and the acid intrusions, and, in the future it may serve as a direction for prospecting in Trans-Baikalia.

In the example of the Kalanguy group of deposits it is possible to see that the deposits are coordinated to the sloping

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wall of the granite block. By this circumstance, perhaps, is explained the occurrence of entire groups of deposits in some sections and their absence in others. It is interesting that the deposits of the more high-temperature type occur either in the granites themselves or in direct proximity to the contact, whereas the low-temperature type, at the same time, are the most remote. Among the granites, for example, occur the Solonech, Konduy, Urulyunguy deposits; outside the granites at a distance up to 1 kilometer occur the Abagaytuy, Ninth Friday and Otsoluy deposits; the most remote are the Kalanguy (4 kilometers), Taminga (2.5 kilometers) and the Sedlov (2.5 kilometers) deposits. However, in this respect, strict regularity is not entirely observed, because in the majority of deposits in one or another degree formations are encountered of one or another type, and the indicated dependence is told more quickly in the principal development of that or another stage of mineralization. In the Sedlov deposit there is even the reverse of the indicated picture. As a consequence of exceptional complexity and insufficient means of studying the geological structure of Eastern Trans-Baikalia and the fluorspar deposits, there remain many obscure questions. In particular, their age is insufficiently concretized. The age of the sandy-shale layer, which serves as a container for a number of deposits (Kalanguy region, Sedlov and others), is rather firmly established as middle-Jurassic. The time of eruption of the post-Jurassic granite intrusions, with which are connected almost all ore developments of Southeastern Trans-Baikalia, and which often themselves are the enclosing rocks for the fluorspar veins, is determined within the limits of the Upper Mesozoic --

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Cenozoic. An indicator of the lower limit is served by the active reaction of it to the rocks of the Middle Jurassic Age, observed in many points, in particular, in the regions of the fluorspar deposits. The upper limit is established by the fact that Upper Tertiary formations, partially sedimentary, partially effusive, occur on the eroded surface of the post-Jurassic granites. In the latter, manifestations of fluorspar nowhere are stated.

Therefore, the age of the fluorspar deposits is determined in extremely general outline -- not more ancient than the Middle Jurassic and not younger than the Upper Tertiary Period.

In addition, it should be noted that the formation of the veins of fluorspar took place in the epoch of tectonic activity of the region, but, apparently, already in the dying phase of it. Traces of this activity in the form of brecciated structure, surfaces and "zerkal" sliding, fracturing and other forms are observed almost in all deposits. Inasmuch as these effects terminated in the already weakened zones -- along the vein body, usually from the under side, they did not lead to the disturbance of completeness of the deposit.

Very interesting, but insufficiently studied, is the question regarding the inter-relationships of the fluorspar deposits with the deposits of other mineral resources, in particular the polymetal, which are connected genetically with the post-Jurassic intrusions. For fluorspar, the association with zinc, lead, partially with copper ores and several other metals is a completely common phenomenon. Such are both the majority of our deposits.

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(Central Asia, Amderma and others) as well as those of foreign countries. In Trans-Baikalia, however, in spite of the enormous prevalence of those and others, they are not encountered together, as a rule.

In the fluorspar veins the ore minerals are not found even in traces. In the poly-metallic deposits, the fluorspar is present, but extremely rare. Thus, it is indicated for 3-4 deposits out of several hundred described by S. S. Smirnov [52].

The intrusive complex for Trans-Baikalia still has not been dissected and it is difficult to judge wherein lies the reason for the indicated phenomenon -- in the features of differentiation of the granite magma or in the diversification of the deposits of these mineral resources and in the connection with the different intrusive cycles. The existence of two cycles in the post-Jurassic intrusive complex is indicated by S. S. Smirnov [52] and Yu. M. Sheynman [72]. Thus, the former in the region of prevalence of the poly-metallic deposits, divides the acid intrusives into Upper Mesozoic and Genozoic, whereas, in the opinion of the author, the majority of ore deposits are connected with the latter. Yu. M. Sheynman, in the region of the lower course of the Onon and Ingody rivers, also hypothetically establishes two phases -- of the more ancient, typical granites and connected with them the hypabyssal rocks in the region of the village of Ulyatuy on the Unde River, and the younger granites, rich in pegmatites, of the central part of the Borshchovochnyy Ridge. If the point of view of the indicated authors is accepted, then the granites of the region of Kalanguy and Solonech deposits must be referred to the more ancient cycle

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the former by analogy with the more ancient granites of Yu. M. Sheynman, and in Solonech, according to the data of I. V. Luchitskiy (see above, the geological description of Solonech), which refers the granites to the "kimmeriysk" -- to the period between the Middle Jurassic and the "turginsk" horizon J_3 -- Cr_1 . Although these data do not emerge from the realm of guesswork, the possibility is not entirely excluded that the formations of fluorspar and poly-metals are separated from one another as a consequence of the difference in time of their formation.

WESTERN SIBERIA

A. L. Ponomarev

DEPOSITS OF FLUORSPAR IN WESTERN SIBERIA

Data on the occurrence of fluorspar in Western Siberia are rather numerous; in the majority of cases they are extremely scarce and bear a fragmental character. In all, according to the data in the literature there are up to 40 points in which fluorspar has been noted; to this number is referred also simply the indications of the occurrence of fluorspar as an accessory mineral. Only two of the largest deposits of fluorspar in Western Siberia, the Suyenga and Irbin, have been studied partially and brought to light most fully in the literature.

SUYENGA DEPOSIT

It is located 85 kilometers to the northeast of the Cherepanovo station of the Omsk Railway and 25 kilometers from the regional center of the village of Maslyanino. The geographical

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coordinates of the region of the deposit are: 84 degrees, 30 minutes -- 84 degrees, 38 minutes E. (from Greenwich) and 54 degrees, 25 minutes -- 54 degrees, 32 minutes N.

The Suyenga deposit was discovered in 1932 by the geological prospecting party of the Western Siberian Geological Trust, which was prospecting for gold ore. In recent years, the deposit has been prospected by that same organization through a party headed by L. F. Tomchik; in addition, deep prospecting pits have been sunk in the vein, ore samples have been taken and topographical and geological maps have been compiled. In 1934, the deposit was visited and partially studied by the geologist A. P. Burov of the TsNIGRI. The description of the deposit, cited below, also was compiled on the basis of materials obtained as a result of these operations and derived by the indicated investigators.

Geological outline. The region of the Suyenga deposit is a slightly mountainous locality with very sloping forms and infrequent outcroppings of original rocks. The relative heights of the locality rarely exceed 100-200 meters.

In the northern and northeastern part of the region there is a continuous occurrence of fine-sheared, frequently sandy and marly limestones, sometimes containing seams of shales. Faunally, these rocks have not been determined; their age is determined by some investigators as Silurian, but by others as Cambrian.

In the western and southeastern part of the region, in conformance with these rocks, occur green and violet-gray shales and rocks of the porphyrite-tufa stratum, the age of which is established

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as Silurian. In the opinion of A. P. Burov, the green shales of this stratum are strongly metamorphized porphyrites and their tuffs. The formation of the latter bore the character of rhythmical submerged eruptions, which also explains their alternation with the normal shales of marlaceous and sericite-clay composition.

In addition to the two indicated phases of the Silurian period, there are in the region small outcroppings of reef limestones, distributed chiefly at the border of these Silurian rocks. They occur in small islets and are represented by compact limestone of grayish-white color. The fauna of corals, bryozoas and brachiopods encountered in them by some investigators is determined insofar as it is possible, as Upper Silurian, but by others it is referred to the Devonian period.

The southern and, in part, the central part of the region is built up by Devonian black calcareous-argillaceous fine-grained shales and phyllites, at variance with those occurring in the Silurian rocks.

All of the rocks of the Silurian stratum are built up in a series of small isoclinal, sometimes, possibly, tilted folds of northeastern trend. By this circumstance, evidently, also is explained the alternation of limestones and shales which is observed in places. The shales of the Devonian stratum of rocks are crumpled into sloping folds of latitudinal trend. The conditions of occurrence of them in the form of strips among the Silurian rocks with abnormal contact, which thin out towards the south, permit the hypothesis that a graben exists here, in the depressed part of which

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the Devonian deposits were well preserved.

The eruptive rocks of the region are represented by effusive and vein phase, chiefly, at any rate by intrusive rocks. Rocks of the porphyritic type answer to the vein phase, porphyritic tuffs to the effusive. Both those and also others are exceptionally strongly changed and approach green shales and porphyrites; the vein rocks form large dikes. According to the age of the porphyrites and their tuffs, apparently, they are referred to the orogeny of the Caledonian phase.

The intrusive rocks of the region are represented by a small block of quartzitic-orthoclase gabbro, which occurs among the Silurian rocks, and by small outcroppings of quartzitic diorite among the rocks of the Devonian stratum. At the time of formation, the intrusive rocks are younger than the effusive rocks. In connection with the indicated intrusive rocks, the rather numerous quartz and quartzitic-carbonate veins of the region are basic magma.

Description of the Deposit

The deposit of fluorspar is coordinated to the sheared Silurian limestones indicated above, which contain an admixture of sandy material. The trend of these rocks near the deposit somewhat deviate from the normal northwestern trend, approaching the meridional. Their dip everywhere is northeastern and rather steep.

In the area of the deposit these rocks are pierced by a

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thick network of carbonates and somewhat more rarely by a network of quartz-carbonate veins. A frequent and sharp change of their thickness leads to the formation of comparatively short lenticular bodies.

With these quartzitic-carbonate veins also is connected the fluorite-bearing region. The fluorspar is found either in the form of a small impregnation in these veins, being coordinated chiefly to their wall parts, or else it forms also a small impregnation in the enclosing limestones. Both in those and also in another case the fluorspar is represented by small violet or lilac-colored grains, devoid of the regular crystallographic forms. The purely quartzitic and carbonate veins are not accompanied by an impregnation of fluorspar. Many quartzitic-carbonate veins also are devoid of it. The appearance of a small impregnation of fluorspar in the limestones always is accompanied by the weak silicification of it. The fluorspar does not form considerable accumulations either in the quartzitic-carbonate veins or in the limestones.

Of comparatively great interest are the accumulations of pure fluorspar in the form of veins and lens which are located in the casings of the quartzitic-carbonate veins. Similarly to the latter, their thickness is extremely inconstant; for short distances they are repeatedly pinched to a complete extinction. The results of prospecting operations from the surface afford foundations for expressing surmises regarding the possible increase of thickness of several of them with depth and regarding the junction of them with the main ore body.

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Properly, the Suyenga deposit of fluorspar, or the main ore body, is one of such almost pure accumulations of fluorspar and possesses a rather considerable thickness. The form and sizes of this ore body remain somewhat unclear. Originally, the form of an irregular lenticular-tubular vein with a steep dip was attributed to it. The extent of this lens was measured at 7.5 meters, the thickness at 2.5 meters. The fluorspar body, apparently, is a complex, irregular vein, which forms beaded bulges and narrowings, possibly up to the complete squeezing out of the vein.

In the upper horizons, the ore body is built up by almost pure fluorspar; according to the degree of deepening, quartzitic-carbonate formations in the form of an irregular form of nodules and bodies of the most various sizes begin to enter into the composition of the ore body. At a depth of 15-16 meters, the quantity of them increases so much that they almost completely displace the fluorspar. In their composition, in addition to calcite and quartz, which are the basic minerals, apatite is encountered in comparatively considerable quantities, more rarely, pyrite, chalcopryrite, fahlerz and galenite, and the secondary minerals covellite, chalcocine, malachite, azurite and limonite.

In the direct contact of the ore body with the enclosing limestones, frequently are observed, also, small quartzitic-carbonate veins. The enclosing limestones, in their turn, are enriched by a small impregnation of fluorspar, chertized to a very slight degree, and are sericitized in close contact with the vein.

The fluorspar of the deposit is represented by three basic

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varieties: compact, dense, fine-grained fluorspar of light colors, banded, and dark-violet. The first two varieties, basically, join the ore body, but the third either is encountered in the form of an impregnation in the limestones, or else forms small bands, passing through in the contacts of the ore body with the limestones.

The dense, fine-grained fluorspar is an aggregate of extremely small grains of fluorspar, which interlock so closely that it is not possible to distinguish the separate grains; cleavage in octahedral form is completely imperceptible, and during cleavage of this fluorspar aggregate a characteristic splintery and, more rarely, conchoidal fracture is observed. Its color in the majority of cases is milky-white and only now and then assumes weak greenish and violet shadings. It is non-transparent and only translucent. With the appearance of pale colors the transparency somewhat increases. The glance on the fresh cleavage planes is from dull to greasy. All of these properties, so uncharacteristic of fluorspar, make this aggregate similar to several varieties of cherty quartz. It is interesting to note the presence in this fluorspar of milky-white, fine bands of fluorspar, which is sharply characterized by considerably better transparency and as if describing the contours of small, subangular bodies. In certain cases their forms recall the form of some shells, but their formation up to now is still not clear.

The banded fluorspar possesses almost all of the properties indicated for the dense fluorspar, and is distinguished from it by the clearer coloring of those same tones, better transparency and a sharply expressed banding, specified alternate and frequent change

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of the fine bands of fluorspar with a different transparency. The broader, up to 0.5 centimeter, bands of rather transparent fluorspar alternate with the considerably narrower band of non-transparent, whitish fluorspar. These bands are located in almost straight lines and strictly parallel to each other, stretching out along the trend of the vein. The different degree of transparency of the fluorspar in this case is explained by the uneven distribution of the numerous inclusions of gases and liquids, in the case of considerable accumulations making it almost non-transparent. The formation of such banded varieties of fluorspar is explained by certain investigators by the replacement by the fluorspar originally of banded limestones of somewhat heterogeneous composition. To the advantage of this hypothesis speaks a certain curvature -- contortion of these bands, which is sometimes observed, reminiscent of the microfoliation in the enclosing limestones.

In the relative location of these two varieties of fluorspar no uniformity was observed. A zonality in the distribution of the differently colored fluorspars was noted only in certain parts of the vein, which is expressed in the coordination of the greenish tones to the center of the vein and their change at the extremities to violets. The latter colors begin to predominate also with the deepening of the vein.

Properly limited crystals were not observed in any of the varieties of fluorspar.

Calcite in the Suyenga deposit is encountered in the form of a coarse-crystalline, light-colored variety, filling the

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quartzitic-carbonate formation amongst the fluorspar. In certain cases it keeps separate in independent accumulations, which are situated chiefly in the periphery of these formations on the boundary between the fluorspar and the calcite. More rarely, it forms purely quartzitic small lenses and veinlets in the fluorspar. In the given cases, the formation of quartz took place later than the fluorspar and preceded the calcite. In addition, considerable quantities of quartz are encountered in the casings of the vein in the form of small lenses and veinlets; here, its crystallization, apparently, preceded the formation of the fluorspar. The quartz of these generations is represented by unbroken formations of milky-white color. Finally, quartz is present in the deposit, the formation of which took place already later than the crystallization of the calcite. It forms small crusts of fine crystals, which cover the walls of the cavities in the quartzitic-carbonate bodies, partially replaces the calcite itself.

Ankerite is encountered exclusively in the form of fine veinlets, replacing the calcite in the fractures.

The sulfides indicated above are encountered in the deposit in very small quantities; their formation took place, evidently, after the crystallization of the fluorspar; they usually are closely connected with the quartzitic-carbonate formations. It is interesting to note the connection of the formation of chalcopyrite with the ankerite and galenite with quartz. The latter sulfide is more side-spread and is encountered in the form of fine veinlets or small, irregular formations.

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The genesis of the Suyenga deposit has been determined as hydrothermal. The source of these solutions, in the opinion of A. P. Burov, is the intrusion of basic rocks, represented near the deposit by porphyrites. The solutions themselves were characterized by low temperature and small content of silicic acid. The crystallization of fluorspar took place, basically, by means of a metasomatic replacement of the limestones by hydrothermal solutions in the zones of crumpling and by strong fracturing of them. The age of the Suyenga deposit is referred to the "tel'bessk" phase of the Caledonian dislocation.

Exploration and the Quality of the Ore

The Suyenga deposit has been explored by means of two prospecting pits and a thick network of trenches. Pit No. 1, sunk in the vein of fluorspar in the part where it bulges, was deepened in 1935 to 37 meters; from it, on the various horizons, a number of cross-cuts was passed through. Pits No. 2, sunk at a distance of 150 meters from Pit No. 1 for the purpose of cutting a small vein of fluorspar, encountered a thicker vein at a depth of 10 meters. The cutting in it of a drift as far as the cross-cut from Pit No. 1 showed the joining of both veins.

The quality of the fluorspare ore of the Suyenga deposit is unconditionally considered very high, which satisfies the requirements of cryolite production. Below, chemical analyses (in percent) of samples are cited, which have been derived by I. F. Tomchik (Table 1).

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Table 1

	Horizon 9.6 Meters	Horizon 10.6 Meters	Horizon 11.6 Meters	Horizon 13 Meters	Horizon 14 Meters	Stock Pile of Sorted Ore
CaF ₂	90.78	88.16	90.51	92.30	94.96	96.30
SiO ₂	4.38	7.14	5.27	1.86	3.20	1.23
Fe ₂ O ₃ + Al ₂ O ₃ .	0.70	0.80	1.68	0.50	0.50	0.99
MgO.....	Traces	Traces	Traces	Traces	Traces	Traces
P. p.p.....	2.72	3.05	1.72	3.25	0.56	0.99
Total	98.58	99.15	99.18	97.91	99.22	99.51

Thus, the average content of CaF₂ in the unsorted ore equals approximately 93 percent; the SiO₂ equals 3.3 per cent; Al₂O₃ + Fe₂O₃ [sic] equals 0.50 percent. By ordinary manual sorting, the content of CaF₂ in the ore may be considerably raised.

The reserves of the Suyenga deposit are not very great. After the prospecting in 1933 in Pit No. 1, down to a depth of 24 meters, in category A₂ + B there was calculated to be 1,066 tons of pure fluorspar. With subsequent operations in 1934, these reserves were increased to 2,000 tons.

In spite of the limited reserves, the Suyenga deposit, owing to its favorable geographical location and the high quality of the ore, undoubtedly, merits interest. The new points discovered in the region of the deposit with outcroppings of fluorspar, as yet not prospecting, make the whole region of the Suyenga deposit a prospect

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in the sense of the possible occurrence of new considerable accumulations of fluorspar.

IRBA DEPOSIT

The Irba deposit is located 125 kilometers to northeast of the city of Minusinsk of the Krasnoyarsk Kray and 25 kilometers from the region center, the village of Kuragin. The geographical coordinates of the deposit are 92 degrees, 57 minutes E. (from Greenwich) and 54 degrees, 51 minutes N. It is located on the slope of the Svintsov mountain, on the left bank of the Bolshoy Irba River, near the village of the same name.

The deposit was known long ago; already in 1893, small prospecting operations were carried out in it by P. K. Yavorovsk. It was examined as a lead deposit and received a negative decision, after which for a lengthy period it was left without attention. During the years 1917-1928, prospecting operations were again carried out at the deposit to a small extent, and these also failed to give positive results. These operations were resumed only in 1930-1932 in connection with the systematic prospecting of the Irba iron ore deposit, which was carried out by the Western Siberian Geological Trust. The extent of this work was small also, and the deposit of fluorspar up to the present time has been insufficiently prospected.

In addition to the enumerated prospecting operations, which have been carried out at the deposit, it has been visited repeatedly by different investigators. In 1934, it was visited by A. P. Burov,

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on the basis of whose manuscript report the present description of the deposit has been compiled.

The region of the deposit, in the narrow sense, is the western slope of the Svintsov mountain, with a total area of 100,000 square meters, with a difference of the bench marks of 42 meters.

The whole region, basically, is built up by crystalline limestones of Middle Cambrian age, among which, in the form of comparatively small bodies of various form, occur syenitic porphyries and dioritic porphyries.

The crystalline limestones in the basic mass are represented by light-gray and white varieties of compact structure. More rarely, a poorly expressed cleavage is observed in it, corresponding to its northwest trend and to the steep dip to the east. In addition to this, among the crystalline limestones, with comparatively great occurrence, are breccia-like limestones and typical calcareous breccia, which are located chiefly near the eruptive rocks or fluorspar ore bodies. In the composition of these breccias, in addition to the limestones, skarnitic formations and syenitic porphyries sometimes participate. The contact minerals, which often play the role of the cement, are represented by sericite, quartz, chlorite, minerals of the epidote-zoisite group, granite and pyroxene. Syenitic porphyry is encountered in these breccias or in the form of comparatively small fragments, which are present together with the calcareous fragments or else in finely-crushed form as a cement in common with the contact minerals.

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The syenitic porphyries have the greatest occurrence in the region of the deposit from among the eruptive rocks. They occur among the limestones in the form of lenticular, but in general, irregular bodies, stretching in the direction of the cleavage of the limestones, having the most various sizes and rather various configurations. Further to the north, beyond the limits of the deposit region, the syenitic porphyry is widely prevalent, and the indicated lens of it, evidently, are the outer part of a large outcropping.

The dioritic porphyries are already considerably less widespread in the area of the deposit, and are represented, basically, by two rather large outcroppings in the northwestern and southeastern parts of the section.

A geological study of a broader area speaks for the fact that the syenitic porphyries and the dioritic porphyries are the products of the solidification of a granite-syenitic intrusion, bearing a hypabyssal character, the age of which is determined as Lower Devonian. The intrusion of this grano-syenitic magma was accompanied by intensive contact change of the enclosing rocks, telling in the formation of typical skarns. To the number of such formations is referred also the iron ore Irba deposit. But the formation of the fluorspar is told already by the post-volcanic activity of the derivatives of this intrusion in the form of dioritic porphyrites.

Properly speaking, the deposit of fluorspar is situated in the center of the described section. The form of the ore bodies

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and their structure is rather complex and, owing to insufficient variety, remain not completely explained. In the opinion of A. A. Onosovskiy, who is studying this deposit, it is seven separate bodies of lenticular form, stretched out in a northwest direction; they are located in two almost parallel straight lines, converging in the southeastern part of the deposit.

The largest and best prospected is the ore body No. 1. It is opened from the surface by several trenches and prospected to a depth of 12.5 meters by four pits and cross-cuts from them. In form it is a steeply dipping, very irregular vein-like body of northwest trend, which extends in conformity with the trend of the enclosing rocks. Its thickness fluctuates from 4 to 1 meter and sharply changes at short distances, creating a number of beaded bulgings and narrowings. As the vein deepens, its thickness, generally, decreases somewhat. The extent of the vein along the trend equals approximately 40-45 meters. In the northwest direction the thickness of the ore body gradually diminishes, and in the southeast direction it either quickly thins out or else undergoes local narrowing, owing to the presence of a vein of syenitic porphyry. Limestone and syenitic porphyry serve as enclosing rocks for this vein, and in the underside, limestones and skarnitic rocks.

Ore body Number 2 is also a short lenticular vein of northwest trend, located in the extension of ore bodies Number 1 and 3. It is opened from the surface by two trenches and by one pit to a depth of 12 meters. The dip of the vein is northeast 45 degrees.

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The extent along the trend is nearly 8 meters; the thickness is up to 2.5 meters and less. The enclosing rocks are skarnitic rocks in the under side and limestones and syenitic porphyry in the upper side. Parallely to the ore body were encountered several small fluorspar veinlets.

Ore body Number 3 is opened from the surface altogether by only one trench and has not been prospected to any depth. It is found in the joining of two lines, in which are located the fluorspar bodies. Its thickness in the trench equals 7.5 meters. The extent and configuration remain unclear. The enclosing rocks are breccia-like limestones and breccia.

Ore bodies Number 4, 5, 6, and 7 are situated in northeast branches and are opened chiefly by surface operations. Only ore bodies Number 5 and 7 have been prospected to a depth by small pits. Their thickness reached 6.8 meters and decreased to 2 meters. The dimensions along the trend and the configuration remain unexplained. The enclosing rocks for them are breccia-like limestones, passing over into typical breccia and syenitic porphyry.

In the opinion of A. P. Burov, the Irba deposit of fluorspar is not separate lenticular bodies and veins isolated from one another, but an entire ore zone, coordinated to places of greatest crumpling and shattering now of the enclosing rocks. This ore zone in form is two unbroken bands of branches of northwest trend, joining at the southeast end. The apparent disconnection of these ore bodies is explained by the presence of large bodies of syenitic porphyry, which is not conducive to the

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deposit of the fluorspar ores. But, in the opinion of A. P. Burov, these bodies of syenitic porphyry, subjected to tectonic dislocation together with the limestones, which led to their shattering, still could not significantly prevent the deposit of the ore and disrupt the completeness of the ore zone.

Joining this ore body as basic components are fluorspar, calcite, quartz and fragments of the enclosing rocks with the products of their disintegration. Less important in its structure are galenite and barite, and very rarely encountered are pyrite and chalcopryite. In addition to this, the slight occurrence of the minerals of the silicified zone -- cerussite, limonite and pyromorphite -- also was noted.

Almost no regularity in the distribution of these components in the ore body is observed. The structure of the ore is breccia-like, which is revealed not only in the presence in it of fragments of enclosing rocks, but also in the breccia-like structure of the fluorspar ore itself.

Different associations of minerals and their structural relationships permit us to distinguish several types of fluorspar ore. One of the most prevalent is the fluorspar-calcite-quartzitic type of ore, which contains, in considerable quantities, fragments and products of the disintegration of the syenitic porphyry; this ore is a small-grained aggregate of grayish-lilac color. The fluorspar, quartz, calcite and the products of the disintegration of the syenitic porphyry -- kaolinite and sericite -- are found in it in close connection with one another. The remains of the syenitic porphyry of

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the most various size which are preserved are rather sharply set apart from the fluorspar ore. The content of fluorspar in it fluctuates from 20 to 50 percent.

The fluoritic-calcitic-quartzitic type of ore without the products of the disintegration of the syenitic porphyry are much less prevalent. If the formation of the first type of ore occurred by means of the replacement of the syenitic porphyries, then the formation of the ore in question took place by means of the metasomatism of the limestones, by which also is explained the absence in it of the products of the disintegration of the porphyry. The size of the grains in this type of ore is somewhat increased. The content of fluorspar also somewhat exceeds 50 percent. Frequently, one of the components -- quartz or calcite -- is absent in it, and the ore is a bi-mineral aggregate.

In the fracture in these ores often are deposited admixtures of fluorspar of a later generation and quartz and calcite. These veins are either mono-mineral or else, which is more frequent, are represented by different combinations of these minerals.

The fluorspar veins are distinguished by the greatest thickness, and among them a zonality is observed frequently. In the ore of the first two types, a quartzitic-fluorspar aggregate accumulates, which alternates with pure fluorspar; the crystallization of it is finished by the formation of large and excellently formed crystals. Frequently, the wall of the fracture at first is covered as if by a crust of comb-shaped quartz, on which already fluorspar accumulates. Well-formed crystals of the latter are in the majority of cases

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completely colorless and with the transparency of water. Color -- if it appears -- always is of pale tones, greenish or bluish.

Barite is encountered in the deposit also in the form of small veinlets, sometimes together with calcite and fluorspar, on the crystals of which it accumulates in the form of small plates.

Galenite, which is encountered in the deposit, rarely forms small inclusions and veins in the fluorite-calcitic-quartzitic ore.

The genesis of the Irba deposit of fluorspar is connected with the hydrothermal activity of the intrusion of dioritic porphyrite. The composition of the fluorspar ore points to the comparatively low temperatures of these solutions within the limits of meso and epithermal. The formation of the ores took place chiefly by means of metasomatic replacement of the limestones and syenitic porphyries, in lesser degree by means of crystallization from the solutions in the cavities and fractures. The age of the deposit is referred to the Post-Taconian phase.

The quality of the fluorspar ore of this deposit is low and is characterized by extremely inconstant composition. The content of CaF_2 fluctuates from 22.5 to 72.5 percent. In several analyses the content of CaF_2 was still lower. But the average content of fluorspar is less than 50 percent. The content of SiO_2 fluctuates in the ore from 8 to 49 percent; $\text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3$ are present from 0.5 to 16 percent. CaCO_3 , the content of which fluctuates from 8 to 15 percent, is always present in the ore in large quantities. BaSO_4 also is present in the ore from 1 to 5 percent.

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By manual sorting the content of CaF_2 in the ore can be increased only insignificantly and, consequently, for its utilization, the ore requires mechanical concentration.

The reserves of fluorspar ore in the Irba deposit also are small. Owing to the insufficient exploration of the deposit and the obscurity of the form of the ore body, different authors indicate different figures for the reserves. M. G. Pysanov determined the reserves to a depth of 30 meters at 30,000 tons of ore. A. A. Onosovskiy reduced the figure to 8,520 tons of ore with an average content of CaF_2 of 47.69 percent; 570 tons of pure fluorspar is yielded in category A_2 . A. P. Burov, on the basis of a study of the deposit raises these figures somewhat, determining the total reserves of the deposit as 12,020 tons of ore, of which 1,920 tons are in category A_2 , with an average content of CaF_2 of 47.9 percent.

In concluding the description of the deposit the possibility should be pointed out of the occurrence in it of small quantities of fluorspar which are suitable for use in the optical industry.

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Data regarding the remaining deposits of Western Siberia in the majority of cases are confined only by a few words; many of them are antiquated and demand examination.

The greatest number of indications concerning the occurrence of fluorspar refer to the poly-metallic deposits of silver, lead, zinc and copper. Fluorspar is encountered in them always in limited quantities as one of the vein minerals. Of such are the following deposits: Zmeinogorsk, Cherepanov, Karamyshev and the Salairsk mines and others.

Another large group of known deposits of fluorspar in Western Siberia is the impregnation of this mineral in the granites and nepheline syenites. To expect any considerable accumulations of it in this type of deposit is scarcely possible. As representatives of it there are: an impregnation of fluorspar in the granite along the Iba River near the village of Budrikha, along the Lower Tunguska River near the village of Strelka, near the village of Pudikova and in the nepheline syenite along the Anara River etc.

Fluorspar in the pegmatitic veins and in the pneumatolytic deposits of wolframite is known, namely: on the Rossypnyy mountain, along the Irkutka River, on the banks of Unkul'-kul' Lake and Bulankul' Lake, in the vicinity of Novosibirsk, along the Angara River, in the Belopetsk and Kolyvanov mines etc. The occurrence of it here also is limited to small quantities.

Most interesting are the extremely weakly illuminated deposits of fluorspar in the quartzitic, calcitic and quartzitic-

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calcitic veins. Representatives of this type of deposit are the veins along the Korbalkha River, the Dzhulukol'sk deposit and veins along the Yan River. Precisely among this type of deposit and most probably of all, in favorable conditions, the possibility can be assumed of the formation of larger accumulations of fluorspar.

In addition to the indicated deposits of fluorspar, findings of it also are known in small quantities in the skarnitic formations and in the form of small and rare impregnations among the sedimentary rocks.

From what has been stated above, it can be seen that large deposits of fluorspar in Western Siberia are not known up to the present time. The most significant deposits of it -- Suyenga and Irba -- possess still extremely limited reserves. The Irba deposit at the same time is characterized by extremely low quality ore. The Suyenga deposit is unconditionally the most interesting, which, in spite of its small reserves, possesses excellent quality ore and has prospects in the sense of the expansion and increase of the reserves, chiefly by means of the occurrence in its region of new fluorspar accumulations.

URALS

A. L. Ponomarev

FLUORSPAR DEPOSITS IN THE URALS

Large fluorspar deposits in the Urals are not known. The fluorspar is encountered in the Urals chiefly in various pegmatite

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and pneumatolytic formations.

Emerald piles are located 50 kilometers from the railway station of Bozhenovo and 70 kilometers to the north-east of the city of Sverdlovsk. The geological structure of the region is determined by the contact of strata of crystalline shales with a granite block; among them thick veins of coarse-grained pegmatites are prevalent. The latter usually are accompanied by considerable accumulations of beryl.

Fluorspar is encountered in the whole area of emerald piles, usually in very small quantities. Larger accumulations of it are concentrated in the Malyshev mine, where it forms separate veinlets, pockets of irregular or lenticular form and small inclusions in the micaceous shale, together with beryl. The dimensions of all of these accumulations are very small.

The fluorspar in the majority of cases is coarsely crystalline, frequently colorless and completely transparent, but partially violet, wine-yellow, and bluish. Well-formed crystals are rare.

In the emerald piles, during the course of several years, it has been extracted with the emeralds. Regarding the amount of extraction (in tons) it is possible to judge from the following data:

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In 1922	nearly.....	50.0
" 1922-23	"	13.6
" 1923-24	"	22.1
" 1929-30	"	25.47
" 1931	"	67.73
" 1932	"	72.23

The extracted fluorspar was treated at the Malyshev plant for reprocessing into enamel. The quality of the fluorspar ore is very high; it is possible that part of it will be utilized for the requirements of the optical industry.

The Boyevsk deposit of wolframite is located 35 kilometers to the south-west of the railway station of Sinarskiy and 2 kilometers from the village of Boyevka.

Fluorspar is present in the quartz veins, which cut through the gneiss-shale strata and the diorite-like rocks, together with the wolframite; the form of the veins is extremely irregular. They repeatedly narrow down to a complete extinction, forming a number of rather thick bulges.

The fluorspar is located chiefly in the casings of these veins; partly, it forms a thick, small impregnation in the enclosing rocks. The greatest accumulation of it is coordinated to the bulges of the veins; it is violet, more rarely bluish-green and colorless. Well-defined crystals are rather rare. The average content of fluorspar in the veins usually does not exceed 7-10 percent.

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In 1932, work on the concentration of Boyevsk ore was carried out by the Uralmekhanobr. The raw material contained 6.7--14.7 percent fluorspar and an insignificant amount of wolframite. The concentrate obtained as a result of concentration contained 94.2--96.3 percent CaF_2 and not more than 0.9 percent SiO_2 . It was extracted in small quantities incidentally to the prospecting and extraction of wolframite. The reserves are very small.

Almost in completely similar conditions, fluorspar is found also in the new, neighboring deposit of wolframite -- the "Third Year of the Five-year Plan".

In the region of the Boyevsk deposit, fluorspar is known in the gravel mines over a rather considerable area. The gravel mines partly are alluvial, partly eluvial. In the sands, which contain the fluorspar, wolframite is also found. The content of fluorspar in the gravel mines fluctuates from 7 to 40 percent.

In addition, in the Urals there are up to 40 indications regarding the occurrence of fluorspar, in the majority in the form of an infrequent impregnation in the granites and nepheline syen^{it}es, small accumulations of pegmatite formations or individual findings in the carboniferous limestones.

To the number of such indications refers the Kurochkin "log" in the Vishnev mountains, where, in the exploitable pegmatite rock, in addition to the predominating feldspar, together with nepheline, ilmenite, black mica and aegirite, small

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pockets of fluorspar were encountered. It is known in the Il'men mountains both in the miascite in the form of infrequent and small formations, chiefly near the calcite, and also in certain pegmatite piles.

D. Sokolov, in his "Handbook on Mineralogy" (1932), indicates the occurrence of fluorspar near Chebarkul'sk Lake, where it forms in the granite, together with mica, unbroken veinlets, dark violet in color; during calcination they acquire an excellent emerald color.

Along the Vishera River, near "Yabrus-kamen'", it fills, together with quartz and calcite, the fractures in the limestone.

There are also very old and obscure indications of the occurrence of large quantities of fluorspar near Kungur station, where it was extracted in its time and was used during the smelting of copper ore in the Yuzovskiy plant.

NORTHERN KRAY

N. S. Lavrovich

M ANDERMA DEPOSIT¹

(¹ The description of the deposit has been compiled on the basis of the account by the geologists, N. A. Preobrazhenskiy and A. Z. Lap.)

The deposit of fluorspar was discovered in the summer of 1932 by the Vaygachskiy expedition to the Yugorskiy Peninsula,

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on the bank of the Karskiy Sea, near the mouth of the Anderma River.

The deposit is situated in a narrow strip stretching in a south-southeast direction from the mouth of the Anderma River deep into the peninsula referred to, extending for nearly 28 kilometers.

The region of the deposit is represented by a chain of flat hillocks with an absolute height of from 19 to 130 meters, the rising of the relief taking place in the direction of the sea. The direction of the chain of hillocks approximately corresponds to the direction of the deposit, that is, north-northwest. The Anderma River is of insignificant dimensions and approximately 25-28 kilometers in length; the width of the channel is up to 90 meters downstream and the average depth is up to 1.5 meters. The maximum width of the valley is 0.4 kilometer.

The stratigraphical profile is composed of:

a) A lower layer, which emerges onto the day surface, represented by dark, compact, small-grained, crystalline limestones without remains of fauna and conditional referred to the Cambrian.

The maximum apparent thickness of the layer reaches 2 kilometers. Upper layers bear traces of continental erosion. Here and there the limestones are penetrated by small dikes and blocks of diabases.

b) A layer of marls and marlaceous limestones lean on the limestones; these have fauna Plathycerus sp., Obolus sp. and obscure remains of corals. The age of the layer, evidently, is

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Silurian. Basically, the presence of pebbles from the lower-lying limestones is established. The thickness of the whole stratum reaches 60 meters. Here and there, at the base of the layer, is found a diabasic covering, strewn under by a conglomerate of pebbles of Cambrian limestone.

The upper horizons of the marlaceous layer are built up by black, clayey, marlaceous shales, which pass over above into sili-coargillaceous shales. The thickness of the layer is insignificant, and its upper parts emerge beyond the limits of the region of the deposit. Among the shales the following fauna is present: small brachyopoda, gastropoda, "ortotseratidy", Olaenus, Asaphus, Megalaspis and Echinospheerites. The latter determine the age as Lower Silurian.

To the west of the Amderma region, the Lower Silurian stratum is built up by black argillaceous schists which pass over above into sericitic-chloritic, sericitic and phyllitic schists. The metamorphization of the rocks is caused by numerous dikes and stratified veins of diabases.

The profile of original rocks, which compose the region of the deposit, is completed with these described rocks.

The whole stratum in the region of the deposit is built up into a large anticlinal fold, stretching out in a northwestern direction 330 degrees. The axis of the anticline dips in a southerly direction. The dip of the rocks in the walls of the anticline has angles from 45 to 70 degrees, the eastern wall having a sharper dip in comparison with the western wall. A large

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part of the deposit is coordinated to the eastern wall of the anticline. In the stratum of Cambrian limestones is observed a number of fault fractures of small size close to the trend of the anticline with a steep or vertical dip.

The age of the basic dislocation, that is, the fold, N. A. Preobrazhenskiy refers to Hercynian folding, precisely to the Ural phase. Secondary fault fractures are referred by him to the "postumnyy" post-Hercynian stresses.

In the layer of sedimentary rocks described above, three forms of vein formation are present: the "amdermit", quartzitic-fluoritic, and the calcitic. All three forms have some genetical connection among themselves.

"Amdermit" veins consist of greenish-gray solid or schistous rocks; in the first case the rock is suggestive of limestones, and in the latter of sericitic shales. In mineralogical composition the "amdermit" is an aggregate of small grains of quartz with a predominance of the two form components.

P. P. Sushchinskiy indicates the following characteristic composition of "amdermit": quartz -- 55.5 percent, sericite -- 27.0 percent, calcite -- 40.0 percent, dolomite -- 4.0 percent, pyrite -- 2.5 percent, and ferrous oxide -- 0.7 percent.

The thickness of the veins fluctuates from centimeters to several meters, more often 0.5 -- 1 meter, with an insignificant length along the trend. The "amdermit" veins, according to the age of the more ancient processes of fluorspar formation, also

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created obstacles for the uninterrupted expansion of the latter. Owing to this, the deposit of fluorspar is dismembered as though into separate blocks of different sizes with steep or vertical walls. The quartzitic-fluorititic veins are coordinated to the fractures of the same order as the "amdermit" veins. Their thickness on the average reaches 0.3 -- 0.5 meter. Their mineralogical composition is diverse. In them are encountered: fluorite, quartz, sphalerite, pyrite, calcite, chalcopryrite, and galenite. The calcitic veins are represented by a thick network of fine veinlets, which pierce the stratum of limestones along the cleavage fractures. The thickness of the veins fluctuates from several millimeters up to 5-10 meters.

The stratum of fluorspar-bearing rocks, as has been mentioned, is located on the crest of a large anticline, near the northeastern wall of it, and is coordinated to a tectonic fracture, parallel to the axis of the anticline, expressed by upthrusts in the weakest spot, namely, at the contact of the limestones and argillaceous shales.

The fluorspar is represented by two characteristic varieties: in the form of almost pure fluorite, which occurs in comparatively large lenses and pockets, concentrated in bands of northwestern trend and separate small inclusions.

In the latter case, the fluorspar is represented by small crystals, pockets, veinlets, veins etc. The enclosing rocks are quartz, limestone and black quartzitized rock, which is, apparently, the final results of the modifications of the limestone by the processes of fluoritization.

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The rocks enriched with fluorspar (chiefly limestones) stretch in a comparatively narrow strip in a northwestern direction 330 degrees, extending for nearly 25 kilometers. The dip of the zone enriched by fluorspar is in conformity with the dip of the rocks. An insignificant part of the deposit along the trend has been dealt with by prospecting, but along the dip the fluoritized zones have been opened to depths of 80-90-100 meters.

In small quantity among the fluoritized rocks are encountered: lead glance, zinc blende, bornite, tetrahedrite and others.

In quality, in regard to the content of CaF_2 , the fluorspar ore also is divided into two basic forms. The first form is high-quality, with a content of CaF_2 from 80 to 95-97 percent, concentrated in the lens and pockets referred to above, and during exploitation requires only manual sorting. But the content of fluorspar in the limestones enriched by it fluctuates within huge limits - from 2-3 to 50-60 and even 70 percent. A content of 30-40-50 percent predominates.

Such a content of CaF_2 in the ore unconditionally demands its concentration.

The reserves, calculated for strata 1, 2, 3, and 5, with an average content of CaF_2 in the ore of not less than 40 percent, are, according to categories: A_2 -- 55 thousand tons, B -- 517 thousand tons, C_1 -- 460 thousand tons, in all 1,032 thousand tons.

The figures of the reserves, which have been cited only for part of the deposit, already make it one of the largest in the

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Union. Further prospecting in the remaining part of the deposit unconditionally will increase the reserves considerably.

Reserves for the high-quality ore, more accurately, the commercial fluorspar, have not been calculated.

The genesis of the deposit is metasomatic, but the age of the fluorspar-formation is not exactly established, and without special assurance of it can be considered variscite.

KAZAKH SSR

A. I. Suloyev

AURAKHMAT DEPOSIT

The Aurakhmat deposit (locally, Obi-rakhmat, which means holy water) is found in the Bostaldykskiy Rayon of the Kazakh SSR, 90 kilometers to the northeast of Tashkent and 3 kilometers from the village of Brich-mulla, on the right bank of the Chatkal River. The geographical coordinates of the deposit are 42 degrees 22 minutes N. and 70 degrees 6 minutes E. of Greenwich. A deposit by the name of Chatkal is encountered in the works of I. V. Mushketov, where the presence of fluorspar along the Chatkal River is first noted. Somewhat more detailed and accurate data on it we encounter in the first place by Ryabinin [44], and then by Veber. In 1916, on the assignment of the ore section of Zemgor, the deposit was visited by A. S. Uklonskiy [64, 65, 66], who devoted a little work to the deposit. In 1924, the deposit was examined by A. Ye. Fersman. In 1924-25 the former Institute of Applied

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Mineralogy carried out an experimental extraction of fluorspar, about 600 tons of ore being extracted, which comprised nearly 10 percent of the fluorite visible from the surface. Since 1930 detailed prospecting has been carried out in the deposit by a party of the SARGRY, on the assignment of Khimrudy. In 1931, by assignment and on the resources of IMS (formerly IPM), a geological-mineralogical party of the MGRI worked at the deposit under the direction of N. A. Smol'yaninov [54]. In order to continue the mineralogical investigations which had been started by IMS, in 1932 a mineralogical-petrographical party was directed by A. I. Suloyev [92]. In the summers of 1934-1935 in connection with the work carried out by TsNIGRI on the subject "A Comparative Study of the Fluorite Deposits of the USSR", the deposit was visited by A. P. Burov [81], whose report contains only data taken by him from previous investigators.

OROGRAPHY OF THE REGION OF THE DEPOSIT

With respect to orography, the region of the deposit is the erosional valley of the Chatkal River, up to 2 kilometers wide, with a meridional direction, bordered by high ridges of mountains with cutoff summits. From the north and northwest, the valley is open. The right bank of the valley in the region of the deposit is built up by three longitudinal terraces and bottom land, which rise up one over the other with clearly expressed steps. The lower terrace rises up over the present-day level of the Chatkal River for 12 meters, the middle one for 25 meters and the upper one for 55-60 meters, with a general direction of the terraces close to

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the meridional. In the formation of the valley of the Chatkal River, in the region of the deposit, erosional processes played a huge role. However, the original meridional direction of the valley, apparently, necessarily deviates because of the fault, which runs through along the contact of two rocks that are different in composition, which trend in meridional direction. In the monotonous background of the terraces emerges a cliff, eroded and broken by wash-outs, which is composed of limestones with fluorite, rising up over the level of the Chatkal River to a height of 45 meters and cuts through the second terrace. Near the base of this cliff a spring flows out with water of excellent quality, which gives the locality its name (Obi-rakhmat).

GEOLOGICAL STRUCTURE OF THE DEPOSIT

The region is built up by limestones and shales of Paleozoic age, which are the northwest termination of the Chatkal Range. This complex of rocks is cut through by numerous intrusions. In the district directly adjacent to the deposit, outcroppings of eruptive rocks are not noted. Only at the crest near Adam-tasha ("chelovek-gora") in at separate points in the latitude of Aulis-kadam-dzhay are observed lamprophyre (syenite) vein intrusions of a schistous nature, insignificant in thickness. The region of the deposit is built up by a sedimentary complex of rocks, different in mineralogical composition and age. The most ancient deposits are the limestones, projecting into the deposits both on the surface in the form of small crags from under the limestone-shale stratum, and also detected to a depth by many prospectings over a considerable

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area. The limestones form an anticlinal folding, a sloping dip to the east and more steeply to the west. The trend of the axis of the folding is close to the meridional. This limestones are represented by a crystalline, light-gray variety; they are close-grained, solid and are broken by numerous fractures in various directions, of which the principal ones are: 1) with a northwest trend 280-340 degrees and a dip to the southwest $\angle$ 30-60 degrees, 2) with an eastern trend 90 degrees and a dip to the north $\angle$ 65 degrees or to the south $\angle$ 80 degrees and 3) with a northeast trend 30-60 degrees and with a dip to the southeast $\angle$ 45 degrees.

The limestones contained a large quantity of fauna. From the fauna collected in 1931 by the Smol'yaninov, M. A. Bolkhovitinov determined the following forms, which are close to the forms of the Upper Carbon: Spirifer cf. tibetanus Dien., Martinia sp., Rhynchonella sp., Athyris pectinifera Sow. and remains of members with a crinoid. Together with the fauna cited, forms are observed also which are close to the lowest Carbon: Productus derbiensis Wood, and Spirifer ex gr. striatus Mart. D. V. Nalivkin, who examined the fauna, refers it to the Upper Tournaisian stage or to the lowest "viza" itself.

According to the nature of the fauna and conditions of their occurrence, these limestones are referred to reef-building. From observations of the relation of the reef limestones and the next stratigraphic horizon of the limestone-shale stratum, it follows that the latter seems to by-pass the block of reef limestones

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from the south-southeast and northeast. Outcroppings of this strata are traced not only on the surface down to the Pil'tau, to the south of the cliff and along the right bank of the Chatkal River, but are revealed in a number of points, also, by underground operations. Thus, spatially, this stratum is coordinated to the base of the middle terrace with a northwest trend of the rocks 300-320 degrees and with a dip to the southwest $\angle$ 55-70 degrees. The stratum consists of interstratified layers of shale and limestone, the latter of insignificant thickness. Among these the shales are the most widespread; in composition they are represented by different siliceous, lime-clay shales with a gradual, unobservable transition of one into the other. The siliceous shales play the dominant role. These rocks are dark-gray and black, finely-schistous, small-crystalline, broken by numerous fractures, and filled by calcite. Considerably more widespread is the group of lime-clay shales, which are schistous, dark or gray with greenish shading, and sometimes with carbonaceous inclusions. The layers of limestone are represented^d by dark-gray, gray, schistous and compact rocks with a considerable quantity of fauna. The latter is distributed irregularly in the limestone. It is characterized by leading "vizeyskiy" (C₁) forms, among which Productus striatus Fisch. is encountered in large quantity. The broken up complex of rocks is of exceptional interest, in virtue of the coordination of mineralization to its contact. At the contact with the ore body, the complex of sedimentary rocks is strongly changed: the limestone-shale layer is strongly shattered, crumpled, sometimes with a formation of breccia, cemented by quartz and partially mineralized, the greatest part of the limestones pass over into

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siliceous (chertized) rocks. The transition from normal limestones and shales to altered varieties of those same rocks is gradual. The next, according to age, are the rocks of the red-colored layer, which are referred to the Tertiary Period (Eocene). Within the limits of the deposit they are weakly developed. Outcroppings of them are encountered in the southwestern part of the region near the mouth of the Pil'-tau, from whence they are traced along the right bank of the Chatkal River (joining the lower terrace) northward to the Adam-tash cliff. The contact of the Tertiary deposits with the carboniferous shales and limestones lying under them is disguised to sufficient degree, partially eroded and covered by present-day alluvium. However, from a comparison of the conditions of occurrence of the Tertiary rocks, observed above the mouth of the Pil'-tau in the outcroppings of the right bank of the Chatkal, with Paleozoic limestones, it follows that the former unconformably lean on the latter. In composition, the red-colored stratum of Eocene rocks is represented by limestone, marl, limestone-shell rock and sandstone. The youngest rocks are the recent alluvial (porous) deposits, which lie on the eroded heads of the Eocene stratum. The dislocational processes, which created the structure and contemporary relief of the region of the deposit is due to two orogenical phases: variscite and alpine. To the number of structural elements of the variscite phase of folding pertains the anticline folding with a trend approaching the meridional, more accurately northwest 300-330 degrees and with a dip to the northeast and southwest. In the whole extent of the axis of the fold, the scarf of which is destroyed by erosion, the core is built up by reef limestones, but the walls of the fold, in relation to the axial plane asymmetrically

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built, are built up by the limestone-shale stratum.

According to the data of measurements of the occurrence of the limestone-shale stratum on the surface and in deep workings (pits and holes), it follows that the southwestern wall of the fold has a more or less large slope, which reaches up to 40 degrees, and the southeastern wall is more slanting, with angles of dip from 8 to 25 degrees. In the applied relation, the existence of an anticlinal fold and its form play an essential role, inasmuch as the mineralization is coordinated to the contact of the reef limestone with lime-shale layer which by-passes it, and is reflected in certain features of the morphology of the ore body.

In this respect, the ^role of the dipping of the axis of the fold in the southern part of the region should be recalled, where a considerable positive development of the lime-shale stratum with more slanting angles of dip is observed.

Of the other tectonic manifestations amongst this complex of rocks there are a number of faults, folds, strata and zones of breaking down, which served as a means for the passage of the ore solutions. Later dislocations were especially strongly manifested in the lime-shale stratum near the surface of contact with the block of reef limestone, which played the role of a moving barrier.

The alpine phase of folding is more weakly developed and was manifested in the southwestern part of the region along the right and left banks of the Chatkal River in the area where the Tertiary (Eocene) rocks prevail.

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Confirmation of this is their strong dislocation with a northwest trend 345 degrees and rather sharp dip to the southwest of $\angle$ 50-75 degrees, as a result of which is observed a certain angular variance between the Tertiary rocks and the Carbon rocks (vize) lying under them. Together with the folding, vertical movements (faults), which occur along the contact of the Tertiary rocks and "vizeyskiy" limestones with a meridional trend and dip of the surface to the southwest, play an essential role in the alpine tectonic genesis. In addition, the observed upheavals of Paleozoic rocks, crumpled in the fold, took place, apparently, simultaneously with the fold-formation of the Tertiary rocks. These movements (alpine), which are referred to the post-ore tectonics, in a certain part of the deposit was reflected in the wholeness of the masses of fluorspar, being accompanied in these cases by a formation of typical breccias, in which the fluorspar plays the role of a fragmental material.

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DESCRIPTION OF THE DEPOSIT

The deposit is a saddle-shaped vein body, the form of which is explained by the structural interrelationships of the limestone and limestone-shale strata. Coordinated to the contact of the indicated rocks which forms the anticline, the scarf of which has been destroyed by erosion, the ore body was preserved only in the walls of the asymmetrical fold and is characterized by extremely inconstant form which changes both along the dip and also along the trend. Basically, the whole ore body is represented by a saddle-shaped vein; it possesses, partially, characteristics which are typical of pockets and lenses also stretched along the contact of the limestones and shales; still more rarely it is represented by small veinlets in the limestone. The average trend of the deposit is meridional. The thickness of the ore zone is extremely inconstant, reaching up to 10 meters on the surface; with depth it decreases considerably in several sections tapering out at a depth of 45 - 50 meters.

Regarding the extent of the deposit along the trend, the data in this respect is insufficient as yet. The western wall of the ore body, deeply washed out by the Chatkal River, is opened by tunnels and trenches for a distance of more than 260 meters. The eastern wall is wider with a dip from 8 to 25 degrees buried under the river deposits; this wall was preserved whole to a greater degree. Apparently the Aurakhmat deposit along the trend is not limited by the known fluorspar cliff and its opened part; of great interest are the indications of ore deposits which have been observed in the limestones 3 kilometers from Aurakhmat to the

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southeast along the Pil'-tau River and 8 kilometers above Aurakhmat along the Chatkal (Shabrez deposit).

On the basis of the genetical and structural characteristics and mineralogical composition of the ore body, it is possible to distinguish several types of ore.

Hornstone or "pnevmatolit" (according to Uklonskiy and Smol'yaninov) is a type of ore consisting of a fine-grained, in places cryptoclastic, aggregate of quartz with impregnations of fluorite and calcite. The color of the hornstone is principally grayish with different shadings of yellowish tones. Non-ore varieties, which consist almost entirely of quartz with hornstone structure, are also observed among the hornstone ore. The hornstone is located exclusively in direct contact with the limestones in the form of insignificant pockets and reveals definite indications of a transition to them. The fluorspar, which is found both in an impregnated state and also in the form of seams in the hornstone and which has irregular, more rarely idiomorphic, forms, is usually dark-violet although it sometimes has other hues and on occasion is even colorless, inasmuch as it is situated chiefly in parts which are furthest removed from the limestone.

The formation of the hornstone is connected with the metasomatism of the limestone as a result of the penetration of solutions in the zones of shattering and fracturing. Regarding the chemical composition of the hornstone, representative analyses are given in Table 1.

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TABLE 1

	Light, non-ore Hornstone	Dark Hornstone with Fluorite
SiO ₂	97.64	80.28
Al ₂ O ₃	0.90	4.68
Fe ₂ O ₃	0.44	0.08
FeO	0.05	0.44
TiO ₂	Not determined	Not determined
MgO	0.05	0.19
CaO	0.64	7.96
Na ₂ O	Not determined	Not determined
K ₂ O		
Loss during calcination	0.56	2.32
Total	100.28	96.05
Loss after processing H ₂ SO ₄ and calcination	-----	4.63
		Total 100.68
Surplus	-----	1.95
		98.73

The quartz-fluoritic type ore comprises a whole, geologically and genetically, with the examined hornstone, and their chief difference is the former's considerable fluorspar content. In addition, the proportions of fluorspar and quartz fluctuate within the most various limits down to the almost complete displacement of quartz

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by fluorite, creating in this fashion a third -- purely fluoritic -- type of ore. In the individual samples it is possible to observe the brecciated structure: small round-angular fragments of hornstone or limestone left intact after metasomatism are cemented by fluorspar or quartz. Barite and calcite, in grains of irregular form are rarely observed among the cemented mass; lead glance still more rarely. This type of ore is exceptionally prevalent and represents the basic mass of fluorspar ore. The fluorite in the given case is small- and large-crystalline, strongly fractured and often crumbled into gravel or powder. It is usually white, sometimes slightly greenish and rose-colored. The broken-up type of ore is characterized by the following two chemical analyses (Table 2).

The fluoritic type of ore is pure fluorspar material which is encountered in the form of small lenticular sections of insignificant sizes located among the quartzitic-fluoritic ore. At the present time, the vein-like lens, occurring in the southern end of the Fluorspar cliff with a meridional trend for a distance of nearly 70 meters and a width of up to 4 meters, is of special interest among ^{ores of this type.} ~~this type of ore.~~ In all cases the fluorite is light, frequently with a zonal arrangement of colors; violet in the center and greenish and colorless in the periphery. The good transparency of the fluorspar, the absence of fracturing with depth which is observed only close to the surface, and the presence of well-formed crystals attract attention. The broken-up type of ore is characterized by the chemical analyses cited in Table 3.

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TABLE 2

	Analysis of a Sample From the Terrace of Tunnel No. 7 (Analyst Khovanskiy)	Analysis of a Sample From Tunnel No. 6 (Analyst Medvedeva)
Ca	40.26	20.66
BaO	4.52	1.21
F	38.05	—
SO ₃	2.39	0.58
CO ₂	1.24	0.11
SiO ₂	14.13	56.62
Fe ₂ O ₃	0.21	0.15
Al ₂ O ₃	0.66	1.47
Results of the Mineralogical Conversion		
CaF ₂	76.23	40.05
BaSO ₄	6.88	1.84
CaCO ₃	2.82	0.25
SiO ₂	13.74	56.62

The fluorspar-sulfide type of ore is very weakly developed; it is observed in the form of a small broken zone in contact with the shales. In composition and structural characteristics this type of ore is extremely similar to the fluorspar variety into which it gradually and imperceptible passes over. A basic distinguishing sign is the considerable content of sphalerite and galenite together with fluorspar and quartz, and the comparatively small variety of minerals. The distribution of the basic components in

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the ore is uneven. A type is separated out with a cockade structure, where lenticular formations of violet fluorite, as it were, are circumvented by the small-grained mass consisting of quartz, fluorspar, galenite and sphalerite. But frequently in these conditions breccia-like fragments with impregnations of fluorite, galenite and sphalerite are encountered. More rarely, it is possible to observe large crystals of light-colored fluorite which are penetrated by irregular veinlets of sulfide minerals. In addition barite and fahlerz are encountered of the minerals of the admixture in the described variety; the former in close coalescence with the fluorite, the latter in close connection with the galenite.

The fluorspar in this sulfide variety, in distinction to the previous ones, is finest-grained and dark violet in color. Its quantity was not taken into consideration but apparently it is small.

The quartzitic-fluorspar breccia is an inferior development among the types of ore examined. It is represented by angular fragments of dark, clayey and carbonaceous shales of the most different size, cemented by quartz and fluorspar. In the majority of cases the fluorite predominates, sometimes completely displacing the quartz; it also forms small impregnations in the fragments of shale. Considerably more rarely the cement consists of some quartz, providing numerous veinlets in the mass of shale, partially quartzitizing it.

Calcitic breccia, like the previous type of ore, in virtue of its sporadic findings and insignificant content of fluorspar, clearly has no practical importance. It consists of large, acute-angled fragments of fine-grained clay shale, cemented by milk-white

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non-transparent, coarse-crystalline calcite with comparatively rare idiomorphic grains of dark-violet fluorite and quartz. In rare cases the components enumerated above, entering into the composition of the cement, did not have fragmental material in them and did not have a breccia-like structure.

TABLE 3

Place of Taking Sample	CaF ₂ (according to difference)	SiO ₂
Trench No. 8 -- 3.31 meters from northeast end, along bottom (sample No. 33)	99.4	0.6
Trench No. 8 -- 4.5 meters from northwest end, along bottom (sample No. 35)	92.1	7.9
Trench No. 7 -- 7.43 meters from northwest end, along bottom (sample No. 37)	100.0	—
Trench No. 7 -- 17.92 meters from northwest end, along bottom (sample No. 38)	99.2	0.8
Trench No. 7 -- 19.30 meters from northwest end, along bottom (sample No. 40)	91.3	8.7

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Secondary calcitic breccia is an inferior development and is observed exclusively in the northern part of the deposit in the form of small, broken bands or lenses. The presence of ore components among the fragmental material of the breccia, that is, fluorspar, permits us to refer it to secondary formations, connected with tectonic dislocations, which occurred in Alpine times. In outward form this type of ore recalls the breccia-like limestone and possesses a dirty-yellow color. Angular fragmental material of breccia is represented by hornstone ore, light-colored shales and dark-violet fluorspar. The cementing substance basically consists of porous, fine-grained calcite of a yellowish-white color. According to the genetical types of ore in the Aurakhmat deposit, the following stand out as having practical significance: (1) extra-high-grade ore consisting of large formations of fluorspar, devoid of admixtures; (2) ore consisting of fluorspar and quartz (the so-called quartzitic-fluoritic type); and (3) low-grade ore consisting of fluorspar, quartz, sulfides and several other minerals.

The high-grade ore is encountered in the deposit in large accumulations in the form of lenses, sometimes of considerable size -- up to 4 meters in diameter, among the quartzitic-fluoritic type. In addition, veinlets of pure fluorspar were observed inside the unchanged limestone. Fluorspar of this sort is light-blue, pure, fractured, and fragile; at the slightest blow it shatters into small pieces not larger than 2-3 centimeters in diameter. Thus, it is difficult to depend on obtaining from this type of fluorspar a raw material that is high-grade and, at the same time, in large pieces. Quantitatively, this sort of ore occupies a prominent place.

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The approximate reserves of it must be rated at 25-30 percent of the total reserves. The content of CaF_2 reaches 100 percent.

Average-grade ore, consisting basically of fluorspar, quartz, and more rarely barite, hornstone and calcite, predominates in the deposit. Therefore, in the exploitation of the deposit the undertaking must be based chiefly on this sort of ore. The amount of fluorspar in it fluctuates within broad limits from 30 to 80 percent. Nearer to the contact of the limestone the replacement of the fluorite by the quartz and the transition of this sort of ore into almost ore-less hornstone take place. The fluorite in the given ore is small- and coarse-crystalline, strongly fractured and frequently crumpled into small gravel, which has resulted in its being given a local name of "sandy" ore.

Low-grade ore which contains sulfides is weakly developed in the form of small, isolated zones in contact with the shales. The ore components are a siliceous-clay material of the shales, fluorite, quartz, sulfides and barite. The fluorite of this sort of ore is fine-crystalline, dark-violet. Its distribution in the ore is uneven; quantitatively insignificant. This ore, which occurs largely with metallic ores, is of conditional importance for fluorite if the ore reserves are present in sufficient quantity.

The mineral composition of the primary ore of the Aurakhmat deposit consists basically of fluorspar and quartz. Of the secondary minerals which have a primary character there are sphalerite, galenite, pyrite, chalcopryrite, antimonite, pale antimony ore, calcite, barite and nacrite. Of the secondary minerals, which are character-

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istic to the zone of oxidation, observed in insignificant quantities on the walls of the fractures or among the minerals of the primary ores, the following were encountered: sulfur, goethite, limonite, malachite, azurite, cerussite, chrysocolla and others. Minerals of the zone of cementation are absent in the deposit. Thus, in the composition of the ore of the Aurakhmat deposit, nearly 20 different minerals are counted. Genetically the deposit is referred by the first of its investigators, A. S. Uklonskiy, to the pneumatolytic as a consequence of which the term "pneumatolit" was also applied to the ore body. N. A. Smol'yaninov speaks positively about the hydrothermal origin of the deposit. As in ^{the case of} the Khaydarkan deposit, the whole complex having minerals, the absence of typical fluorine-containing pneumatolytic minerals, and the character of the change of the enclosing rocks indisputably testify to the advantage of the hydrothermal nature of the deposit. If volatile products also participated in the process of mineral formation, it was only in the capacity of components which were active in the aqueous solution. The question regarding the focus and connection of this solution with any intrusions is still obscure up to the present time. One kilometer from the deposit is stated the outcroppings of eruptive rocks in the form of small veins of syenite. The basic minerals of the ore body -- quartz and fluorspar -- basically developed through the replacement of the limestone and in considerably lesser degree, in similar fashion to the zinc blend, the replacement of the clay material of the shale. In rare cases, in cavities of the ore the free crystallization of minerals from solutions was observed. Here there is a possibility of distinguishing four phases

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of the processes of mineral formation. The first, clearly expressed but insignificant, silicic acid phase of the process alternates with the powerful second phase of the silico-fluorine solutions which is connected also with the crystallization of the sulfides. The third, the carbonate phase which apparently followed the second without a break, makes use of a more considerable amount in the deposit than was noted by previous investigators. And, finally, the fourth, the "gipergenny" phase is characterized by the formation of different secondary minerals, connected with the action already of the descending cold solutions. The interrelationships and order of formation of the different minerals of the deposit is well-seen from the genetical scheme (Figure 1). Regarding the temperatures of the solutions, nothing can be said with complete positiveness because of the absence of any exact data. However, judging by the broken up association of minerals and the genetical connection of the fluorite with the nacrite, the process of mineral formation took place at comparatively high temperature and low pressure. From a comparison with other known deposits in Central Asia, it follows that the Aurakmat deposit lies at the boundary of the transition of the epithermal deposit into a mesothermal. The age of the deposit is not completely clear; resulting from indirect indications, it is possible to attribute to it variscite age. The exploitation and industrial utilization of the deposit, in spite of its old reputation and protracted prospecting, is still in the beginning stage.

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With the basic reason for the slow and incomplete utilization of the deposit, it is necessary to consider the limited extent of prospecting, which clearly does not answer those tasks facing the ore administration with respect to the quickest mapping of the ore body and the development of the prospects of the deposit to a depth, and the absence of the application to its study of the complex method of the IMS.

Minerals	Silicic Acid	Fluorilicate	Carbonate	[Hypergene]
	Phase	sulfide Phase	Phase	"Gipergen"
				Phase

Pyrite
 Quartz
 Fluorite
 Barite
 Zinc Blende
 Lead Glance
 Pale Antimony Ore
 Nacrite
 Calcite
 Sulfur
 Goethite
 Malachite
 Azurite
 Limonite
 Cerussite
 Chrysocolla etc.

Figure 1. Genetical scheme of the mineral formation of the Aurakhmat deposit

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On January 1, 1933, the reserves of fluorite were determined by prospecting at approximately 670,000 tons: A₂ -- 70,000 tons, B -- 230,000 tons, C -- 370,000 tons.

On the basis of the latest, most strict calculation, which was carried out by the geologist of the Aurakhmat ore administration, E. Kh Gol'dshmit, according to the data of prospecting in 1934, the total reserves of the Aurakhmat deposit are determined at 482,914 tons, or in category A₂ -- 133,755 tons, B -- 113,859 tons, C -- 235,300 tons. Economico-geographical conditions of Aurakhmat are completely favorable for the development here of a large enterprise. The proximity of the Chatkal River and the construction in the neighborhood of the powerful Chirchik hydrostation completely assures the concentration plant under construction at the deposit of water and electricity. The enterprise can be assured also of manpower because of the population of the large village of Brich-mulla nearby.

BADAMSK DEPOSIT

A. I. Suloyev

The Badamsk deposit is found on the right bank^K of the Badam River, a tributary of the Arys, among crags and cliffs, difficult of access from the side of the river, at a height of nearly 250 meters above the Badam River. The geographical coordinates of the deposit are 42 degrees 25 minutes N. and 69 degrees 05 minutes E. of Greenwich. Administratively, the region of the deposit is included in the Chimkentskiy Rayon of the Kazakh SSR. The deposit is situated 65 kilometers to the south of the town of Chimkent. Pervomay Village is the nearest, largest population point. Other settlements in the neighborhood are the small

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"stanovishcha" of Kirgiz and the Badamsk Kolkhoz apiaries. The Badamsk deposit was discovered in 1926, by the geologist Kolov. According to data collected by the latter, he was able to characterize the deposit as a fluorspar deposit with a vein 100 meters in extent and a thickness up to 20 meters, and with a content of CaF_2 of 30 - 50 percent. In 1927, in a report, presented by Kolov to the Chinkent Ispolkom [Executive Committee], the fluorite reserves are determined at 688,000 tons. In 1928, the deposit was visited by N. Smol'yaninov [53] for the purpose of studying the conditions of occurrence, genesis and rating of the deposit. Detailed investigations of the deposit were carried out in 1930 by the Badamsk party of the Institute of Non-metallic Mineral Resources, under the direction of K. Yu. Kvokov [84]. The report was not published; in it there are the geological characteristics of the region and the economic evaluation of the deposit. In addition to the material supplied, a study of the ore by Mekhanobro was carried out for the purpose of clarifying the possibility of utilizing the ore as fluorspar.

In 1931, by assignment and on the resources of IMS (formerly IPM), the deposit was visited by the geological-mineralogical party of the MGPI, under the direction of N. A. Smol'yaninov [54], for the purpose of collecting material for the inclusion of the Badamsk deposit in general comparative rating of the fluorspar deposits of Central Asia. In the summer of 1934, in connection with the work carried out by the TsNIGRI on the theme "Comparative study of the Fluorite Deposits of the USSR", the deposit was visited by A. P. Burov [81]. The description of the deposit which follows is based on the works of N. A. Smol'yaninov and K. Yu. Kvokov

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referred to above; the report of Eurov contains no new data.

OROGRAPHY OF THE REGION OF THE DEPOSIT

With respect to orography, the region of the deposit is represented by the Badam mountains, which are the extreme southwestern spurs of the Talas Ala-tau. There are altitudes of separate summits up to 500 meters above the level of the Badam.

The Badam River, a mountain river several meters wide, cuts through a thick stratum of Paleozoic limestones in the region of the deposit, forming a deep ravine; its source is located 15 kilometers from the deposit. From both sides, almost parallel gullies, deep and rocky, usually with small springs, open into the ravine of the Badam River. Access to Badam from both sides of the banks is extremely difficult in view of the height and steepness of the banks; passage through the Badam ravine also is very difficult, in several places completely impossible. There is a single more or less convenient passage at a section of the deposit through Badam-kul'say (from the side of the right bank) and further on down along the Badam, halfway up the left slope of the ravine.

GEOLOGICAL STRUCTURE AND TECTONICS OF THE DEPOSIT

The sedimentary complex of the Badam deposit, represented by limestones and conglomerates, is referred by Ye. V. Iranov to the "vize" stage. Stratigraphically and lithologically, the limestones, occurring in the basic sedimentary stratum, are subdivided into several kinds. The so-called basic limestones, geologically referring to the lowest horizons, which are observed on the right

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bank of the Badam River in the center of the anticlinal folding of the deposit, are fine-grained, with a big, difficultly traced cleavage. The encrinitic limestones lean on the limestone of this type, the former subdivided by Kvokov into two blocks - the upper, with a thickness of 20 meters, and the lower, with a thickness of 25 meters. The rocks of the upper block are represented by gray limestones, uniformly stratified, of a crypto-elastic character, with rare and indistinct remains of "goniatity" and brachyopod. The limestones of the lower block, which join the scar^p of the anticline, clearly of a fragmental nature, are distinguished by their spottiness and variegated coloring. Between the broken up varieties of encrinitic limestones exist gradual and imperceptible transitions. The next stratum of rock, deposited on the encrinitic limestones, is represented, basically, by the conglomerates with alternating limestones, schistous, slightly redolent, dark-gray. This stratum is observed in the ridge of the left bank of the Badam-kul'-say. The conglomerates, with excellently rolled pebbles, display a banding as a result of the sorting of the latter. That same sequence of the complex of rocks is characteristic also for the anticlinal fold, which is found south-west of the fault. To the north-east of it "goniatit" limestones are prevalent, which, in direct contact with the fault trace, pass over into siliceous limestones, finely-stratified, ocher-gray, with exceptionally sharply expressed contortion. In them are observed layers of 5 - 6 meters with accu^lulations of "goniatity". The horizon of "goniatit" limestones is covered by black limestones of rather various composition with a general thickness reaching 160 meters; they alternate in the beginning with rose-tinted, later with finely-stratified gray limestones. In the south-west corner

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of the region, biotitic porphyrites crop out, which intrude in the form of a vein into the stratum of limestones and represent the effusive phase of granodioritic magma. Beginning below the Barit Valley (~~run~~^{run}ing to the east beyond the Badam-kul'-say), at the contact with the conglomerates, it passes over to the right bank of the Badam-kul' and below branches out on both the right, as well as on the left, bank of the Badam. Among the intrusive rocks, Kvokov notes granite, observed somewhat above along the Badam River, near the so-called Upper apiary and on the watershed of the hill at the source of the Badam, and enstatite-augitic diorite, which occurs on the left bank of the Badam near the water itself in the form of a small outcrop. Besides the rocks which have been considered, lithoclastic tuffs enter into the geological structure of the region along the right slope on the lower part of the Badam-kul'-say, with a predominance in it of rocks over minerals; in origin, Kvokov considers them as syngenetic to the eruption of porphyrites. The sedimentary complex of rocks in the region of the deposit is crumpled into a small anticlinal folding of Hercynian age, which is a secondary development in the western wall of the main fold, the axis of which passes through 4 kilometers more to the east of the deposit. The axis of this secondary anticlinal fold does not have a completely expressed direction, changing from the meridional to north-west 300 degrees, with the formation of an arc, the convex side of which is turned to the north-east. In the center of the fold the rocks are strongly crumpled, and the fold itself is somewhat tipped to the south-east. The deposit is coordinated to the fault trace, which runs almost parallelly to the axis of the fold in the center of the anticline. The plane of the fault has a dip to the north-east at an angle of nearly 70 degrees. The fault trace was deter-

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mined by Kvokov on the basis of the difference of the rocks. In the southern part, the fault fracture is divided into two branches, of which the eastern is considered by Kvokov as the continuation of the fold; the southern direction does not depend on the dislocation of the rocks.

DESCRIPTION OF THE DEPOSIT

The ore body occurs in the fracture of the fault and penetrates through the cleavage into the wall rocks. Owing to the form of occurrence, the deposit is considered as a vein deposit; however, similar to the Khaydarkan, here it is difficult to delimit the idea of the ore* [Errata: Page 134, Line 10: "ore" should read "vein"] from the ore zone. The zone of mineralization has an unequal thickness; in places in it occur considerable bulges, up to 10 meters. In other places it narrows down to 1 meter. The extent of the ore zone is traced along the trend on the right bank of the Badam River for 660 meters, on the left bank among the cliffs, which are difficult of access, for 140 meters. Regarding the extent of the deposit in depth, there is no data at the present time in this respect. The ore body is subdivided into several types according to mineral composition.

Ore hornstone or siliceous rock (according to Kvokov -- quartzite) represents almost entirely the limestone replaced by silica, with a large or small quantity of finely-diffused violet fluorite, more rarely barite, and, in the capacity of a small admixture, fahlerz. Such a change usually does not go far into the limestones, but is limited to a comparatively narrow zone

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(in contrast to Khaydarkan). In form and properties, fluor-spar of this type of ore recalls the fluorite of the ore breccia of Khaydarkan, but only has a secondary importance here. The distribution of the ore components in the hornstone is not uniform; the proportion of quartz and fluorite fluctuates within the most various limits, down to the complete displacement of the fluorite and barite by quartz, creating in this fashion a ore-less hornstone -- jasper-like rock.

Barite-fluoritic type of ore, which plays the predominant role in the deposit, is, properly speaking, a vein body, occurring as veinlets of slight thickness between the layers of hornstone and, more rarely, limestone; quartz is absent in the veins. A little fahlerz is admixed, in the upper horizons of malachite and azurite, with a number of secondary sulfides. The common occurrence of the basic minerals fluorite and barite is so constant for the ^whole region of mineralization that one can speak only regarding the variations of the content of them in the ore, but not about the complete elimination of any one of them. Hypothetically, it is possible to assume the possibility of finding barite free of fluorspar more quickly than the contrary. Analyses of samples, carried out by K. Yu Kvokov ^{indicate} ~~show~~ fluctuations in the content of BaSO_4 (36 analyses) from 29 to 83 percent, and CaF_2 (12 analyses) within the limits of 2.14 to 28.84 percent. The content of copper (36 analyses) fluctuates from total absence (in three cases) to 1.88 percent. A principal difference between fluorite in the wall rock and fluorite of this type of ore is not observed.

Fluorite of the type under consideration is characterized by the size of the grain, a well-expressed crystalline form,

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the purity of individual elements. It usually is coordinated to the casing part of the vein, where its crystals are located either in continuous series or in separate crystals -- clear-violet cubes. Very rarely there are well-formed crystals of large size inside the vein barite. In this case, the fluorite is distinguished by light color. Dark violet varieties are observed usually in the fine veinlets in the sandstone and generally in conditions of close contact with the sedimentary rock.

Together with the described type, pockets and veins that are thicker and more uniform in composition are encountered; they are comparatively rare and scattered. The thickness of the more or less purely baritic veinlets fluctuates from 0.30 to 1.5 centimeters. A single large pocket of fluorspar on the surface has an area of nearly 5 - 6 square meters; it is accompanied by a baritic fringe and includes a certain amount of barite within its mass. As a consequence of the content in the ore of fluorspar and barite, reserves of which are considerable, the extraction of this sort of ore must be carried out under conditions of the complex utilization of all the components of the ore.

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Minerals	Stages of Mineral Formation			Stage of
	Beginning	Middle	Final	Secondary Changes
Quartz				
Fluorite				
Barite				
Fahlerz and other				
Sulfur Compounds				
Malachite				
Azurite and Others				

Figure 1. Sequence of formation of minerals of the Badam Deposit.
(according to M. A. Smol'yaninov).

The mineral composition of the primary ore of the Badam deposit is characterized by the following basic minerals; barite, fluorite and quartz (hornstone). Among the secondary minerals, which have a primary character, are found: Fahlerz, calcite and farnatite. The deposit is poor in secondary, neogenic minerals, which characterize the oxidized zone. Covellite, copper glance, copper pyrites, witherite, malachite, azurite, chrysocolla are present only in insignificant quantities. According to the association of minerals and the nature of change of the enclosing rocks, there is a basis for considering that the deposit is hydrothermal. The formation of the basic minerals of the deposit took place at different times; they were crystallized in a definite successive change, which is seen well in the genetical table of mineral formation (Figure 1).

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The formation of quartz (hornstone) took place, basically, because of the replacement of the limestone in the beginning phase of ore formation, when the thermal springs were enriched with silicic acid. It is possible to suppose that this process of change of the enclosing rocks took place even before the beginning of the opening of the ore fractures. In the later stages of mineral formation the opening of the ore fracture and development of it by solutions, enriched with ^Ccarbon dioxide on account of previous reactions, takes place in connection with tectonic dislocations (the fault). In any case, apparently, the opening of the fractures produced an outflow of mineralized solutions, from which were precipitated, in conditions of the free crystallization within a broad temperature range, first ~~fluorite~~ fluorite, then ~~barite~~ barite. Thus, on the basis of what has been stated above, it can be assumed that the material composition of the solutions changed with a sharp change of temperature conditions, or else a gradual change of the solutions took place over a period of time. In connection with this, the moment of completion of the formation of the deposit is characterized by the appearance in the thermal process of copper sulfide solutions, with which is connected the crystallization of fahlerz and other sulfur compounds, which are, however, of no serious importance for the deposit.

In age, the deposit is referred to the Hercynian period and is found in genetical connection with the neighboring intrusion of porphyrites, which were able to discharge, in the post-volcanic phase, the thermal springs which penetrated into the fractures caused by the fault.

On the basis of a calculation, carried out by K. Yu Kvokov

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in 1930, the approximate reserves in the deposit to a depth of 100 meters below the level of the Badam River are as follows: fluorite- 360,000 tons, barite -- 830,000 tons, and copper -- 11,600 tons.

In 1927, in a report presented by Kolov to the Chiskent Ispolkom [Executive Committee], the reserves of fluorite were determined at 688,000 tons. Thus, the reserves of the deposit are sufficiently great on the part of each of the two minerals (fluorite and barite), but there is no adequate basis for a calculation at great depth -- possibly a considerable reduction. The average content of copper -- 0.7 percent -- must be acknowledged as high, inasmuch as samples were taken exclusively from the enriched oxidized zone.

SECONDARY FLUORSPAR DEPOSITS IN KAZAKH SSR

A. L. Ponomarev

In addition to the large, commercial deposits of Aurakhmat and Badam, a large number of places in the huge territory of the Kazakh SSR with occurrences of fluorspar are known, but in the majority of cases, the data we come upon concerning them is exceptionally scanty, fragmental and often obsolete.

From the whole number of registered findings of fluorspar, undoubtedly, the deposits and whole region, which is found in the south-eastern part of Kazakhstan, near the town of Dzsharkent, merit attention. Here, according to the data of N. G. Kassin, on the south-western boarder of the Katu mountain, to the east of the village of Aral'tyube, at the contact of the granosyenite with

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tuffs, a quartzitic vein of up to 0.4 meter thick passes through, with a considerable content of fluorspar and apatite.

The other deposit of fluorspar in this region, also pointed out by N. G. Kassin, is situated in the pass between the Kyzyl-kiya and Taldy-su rivers, to the east of the settlement of ^Poput. Here, in the quartzitized limestones, near their contact with the granites, quartz veins with a thickness up to 5 meters pass through, in which is encountered fluorspar in the form of separate pocket-like accumulations.

Mushketov and Voznesenskiy also point out the occurrence in this region of a considerable accumulation of fluorspar in a small vein of quartzitic rock, which is found not far from a deposit of iron glance in the Kyzyl-kuro (koro) ravine of the Katatau mountain, 20 kilometers to the south-west of the Aynabulaksk station.

Somewhat more to the north of this region, toward Lepsinsk, 10 kilometers to the south of Arsalan, an occurrence in crystalline shales is indicated by Tatarinov and Reutovskiy not far from the left bank of the Kolsala River (the left tributary of the Bakanal) of a large quantity of fine quartzitic veins with lead glance and green and violet crystals of fluorspar. Three kilometers farther up along the Koksals River a similar fine quartzitic vein is indicated, with a considerable quantity of fluorspar.

In addition to this, V. Lipskiy refers to a finding in the river deposits of detritus of fluorspar, in the region of Kopal'sk along the Kara-taya River.

All of these indications, in spite of their fragmental

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nature, undoubtedly make this region of interest also as a prospect in the sense of the possibility of the occurrence of new large deposits of fluorspar.

Not devoid of interest are the occurrences of fluorspar in the northern part of Kazakhstan. The deposit most known is the Bayanal' deposit, at which in 1935 work was carried out on a small scale by the Western Siberia Department of the GMS. Here, among the various effusive rocks, quartz veins pass through, with a thickness up to 1 meter and a content of fluorspar. Several of the veinlets, somewhat less thick, are filled with pure fluorspar. There are no developed veins of industrial significance, but this does not exclude the possibility of finding new, larger veins. The region of the deposit is very badly eroded.

There are also indications of fluorspar and amethyst at the Solomonov and Mikhaylov mines of the 'Eighties of the last century, 75 kilometers to the east of Karkaralinsk.

Findings of fluorspar near the Yanishev station are known also along the Irtysh River, in the Kokchetav mountains and near Petropavlovsk.

The advantageous geographical location of all of these deposits near convenient means of communication and the large industrial development of the Karagandinsk region makes them of especial interest.

In conclusion, regions of Kazakhstan adjoining to the already known large deposits of Aurakmat and Badam, on the territory of which fluorspar was found, also should be mentioned.

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A. I. Suloyev

KHAYDARKAN DEPOSIT

The Khaydarkan deposit is located in the northern foothills of the Alay Range; the geographical coordinates of the deposit are 39 degrees 57 minutes 59 seconds N. and 71 degrees 20 minutes 24 seconds E. of Greenwich. Administratively, the region of the deposit is within the Uch-Kurganskiy Rayon of the Kirgiz SSR. The nearest large center of population -- the village of Sokh -- is 16 kilometers to the west, in the flourishing valley of the Sokh River. The deposit is located 80 kilometers to the south-west of the town of Fergan.

The deposit of Khaydarkan, as well as a number of other deposits of mercury, coordinated to the Yuzhnofergansk ore belt, was known and developed in antiquity, which fact is attested also in the name Khaydarkan -- the great mine. According to the data of the archeologist M. Ye. Masson, signs of the extraction of mercury are encountered as early as the 10th century. In any case, the development of Khaydarkan was begun, apparently, not later than the 10th century and came to an end in the 13th century. Circumstances confirming the ancient development of Khaydarkan are the huge cavelike developments, excellently preserved, which were first discovered by the geologist Sosedko [60] and described by Saukov [46,47,48]. In present-day literature, indications of the presence of mercury in the Fergansk region are found in V. N. Veber, who studied the Yuzhnofergansk region in 1909 - 1910. His prospecting

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of the deposit in 1915, however, brought no results. Only in 1926 was the Khaydarkan deposit opened by the prospecting party of V. Popov and A. Sosedko, on assignment from the trust "Rare Elements", ^{who} ~~and~~ compiled the first geological map of the deposit, unpublished up to the present time.

In 1927 and 1928, the deposit was studied by A. A. Saukov and A. V. Moskvina, who compiled a geological map and carried out a preliminary sampling of the Main ore field. In 1930, the prospecting operations were continued by Saukov, which were concentrated chiefly on the Main ore field. All of this time, the deposit was considered as a mercury deposit. Only in 1931, when industrial prospecting was begun according to the direction of Glavredmet, was attention turned to the presence here of the industrially important fluorspar. In 1931, on assignment and resources from DMS (formerly IPM), the geological-mineralogical party of the MGPI, under the direction of N. A. Smol'yani-
nov [54], worked at the deposit, with the purpose of studying the mineralogy of the deposit and of the development of its industrial importance as a source of fluorspar. In order to continue the operations which had begun in 1932 by DMS, in 1932 a mineralogical-petrographical party was directed by A. I. Suloyev.

The results of the investigation carried out by this party are set forth in the work of A. I. Suloyev and A. L. Ponomarev [61], in which are produced the detailed geological, petrographical, mineralogical and industrial-economical characteristics of the Khaydarkan fluorspar, cinnabar and antimony glance deposit, which is based on a series of new data. In addition, the ores supplied by this party were studied from the technological

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point of view by the Institute of Mineral Raw Materials, for the purpose of ascertaining the possibility of a complex utilization of the ore. In 1933, the deposit was visited by an engineer of Giredmeta, O. K. Kaminskiy, chiefly for the purpose of calculating the reserves of mercury, antimony and fluorspar and determining the economical value of the deposits of the Mednyy Mountains. At the same time, in 1933, the deposit was studied by I. K. Zaytsev, for the purpose of making a hydro-geological investigation. The latter collected a large quantity of paleontological material, which made it possible for him to refer the rocks of the southern slope of the Plavikovyy and Mednyy mountains to category C_1^2 and the rocks of the northern slope, beyond the ore breccia, which is limited from the north by a tectonic line, to category S_2 . In the summer of 1934, in connection with the operations carried out by TSNIGRI on the theme "A Comparative Study of the Fluorite Deposits of USSR", the deposits was visited by A. P. Eurov [81], whose work added nothing new to the knowledge on the deposit. Among the operations of 1935, the work of the geologist Poyarkov should be noted; this work was conducted according to the direction of Giredmet, in connection with the intensified prospecting of the Khaydarkan deposit.

OROGRAPHY OF THE REGION OF THE DEPOSIT

With regard to orography, the region of the deposit is the broad, 7 - 8 kilometers wide, Allaudin (Khaydarkan) valley, latitudinal in direction, bordered by high, sharply dissected mountain ranges -- spurs of the Alay Range, which runs in that same direction. On the south, the valley is bound by the Sharkrane, Guratyn and Gauyan ranges; on the north, by the Ishme-tau and Kara-

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archi ranges, the smoothed down spurs of which, descending to the valley, form the section in which the deposit is located. From the south and southeast, the valley is closed up by the Metingbel' ridge (with a pass), built up by a layer of conglomerates. To the west, down to the Sokh River, the valley is open along its entire length. The Ishmetau Range is high (2,624 meters), stretched out in a latitudinal direction, in conformance with the predominating trend of the rocks, a range with smoothed down slopes and a narrow crest, built up by limestones. The southern slope of the Ishme-tau Range, devoid of a plant covering, is dissected by a series of ravines (in Uzbeksay), with rather sharp angles of dip, which bear a number of springs in their upper parts, with a very insignificant discharge of water and toward the end of summer completely drying up. The fluctuations of altitude are characterized by the following data: the absolute elevation of the valley near the settlement of Khaydarkan, according to the data of I. D. Khongolovich, is 1,680 meters (summit of the central cone) and 2,624 meters at the summit of the Ishme-tau Range, according to Saikov. Thus, the fluctuation in altitude within the limits of the deposit is 800 meters. Basically, the relief of the region is explained chiefly by erosional processes. The multi-natured forms of relief which exist at the present time are explained, in large degree, also, by the petrographic composition of the rocks. Sections, built up by limestones and ore breccia, stand out against the general background with rocky cliffs and ridges, while at the same time, other sections, built up by shales, from smooth eroded and "zadernovanny" slopes. This phenomenon is noted most in the relief of the

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Plavikovyy mountain, where it is observed among two ridges of limestones (southern and northern) as if of saddleshaped form, which is explained exclusively by the presence here of strongly eroded shales. Among the tectonic factors taking part in the formation of the relief, disjunctive dislocations played a huge role. This is supported by the fact that the majority of ravines -- saya -- and the direction of the separate parts of the valleys coincide with the direction of the basic tectonic lines.

GEOLOGIC STRUCTURE AND TECTONICS OF THE DEPOSIT

The sedimentary complex of the Khaydarkan deposit is characterized by the development of limestones and sandy-clayey rocks. The most ancient deposit, represented by the limestones, crops out along the Ishme-tau in the form of three broad ridges of almost latitudinal trend, with a dip to the south at an angle of $\angle 45 - 80$ degrees. In age, the limestones belong to different systems: Silurian, Devonian and Carbonaceous. These rocks are broken by two systems of fractures. The first system is represented by a north-west trend within the limits of 280 to 340 degrees and a dip to the north-east $\angle 70 - 80$ degrees and south-west $\angle 50$ degrees. The second system of fracturing is expressed by a north-east trend $40 - 75$ degrees and a dip to the south-east $\angle 45 - 60$ degrees. The southern ridge of limestones, on the southern slope of the Ishmetau Range, alternates with a sandstone-shale stratum, which is referred, on the basis of the presence in it of carbonaceous layers of limestones, by Saukov, and later also by Suloyev and Ponomarev, to carboniferous age. From observations of the relation of the rocks of the sandy-clayey and limestone formations, the overlapping of rocks of the sandy-clayey, carbonaceous stratum

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by Silurian limestones is clearly established. The sandy-clayey stratum in the area plays a dominant role in the region of the deposit, having, on the average, a latitudinal trend; in the eastern part of the region, within the limits of the Main ore field and Kara-archi, it occupies a broader strip than in the western part, in the region of the Plavikovyy mountain and the Dange Ravine. The rocks of the sandy-clayey stratum in question are intensively dislocated, tilted and altered in various degree. The sandstones occupy a subordinate position in relation to the strata of shales, and are encountered in the form of seams in the shales, more rarely among the limestones. The color of the sandstones is gray or dark-gray. In their lithological composition the sandstones are sub-divided into sericite-argillaceous and siliceous-calcareous varieties, which are passing over, usually, into the analogous varieties of shales, on the one hand, and, on the other, through the coarse-grained limestones into conglomerate-like rocks. In general, fine-grained sandstones of comparatively small thickness-- from several centimeters to 2 - 5 meters -- predominate. The shales are most prevalent amongst the sedimentary complex of rocks of the region. They are represented by various siliceous, silico-sericitic-argillaceous, silico-sericitic, argillo-calcareous and carbonaceous varieties, with gradual transitions from one into the other. The first three varieties of shales are most prevalent. These rocks are fine-grained, dark-gray or brown, schistous as a consequence of the alternation of the darker rocks, enriched with clay or layer of ferrous oxide. At the contact with ore breccia, the varieties of shales in question pass over into compact and fine-grained, light-blue, greenish, yellowish and brownish silico-sericitic shales -- rocks which rarely are en-

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riched with fluorite. N. A. Smol'yaninov identified this rock as "terra rossa", A. I. Suloyev and A. I. Ponomarev consider these formations with the shales which were changed by hydrothermal ore solutions. Considerably less prevalent is the group of argillo-calcareous shales, which are observed chiefly at the contact with the limestones, with gradual transitions of the one into the other. Carbonaceous shales on the surface are almost never encountered, but in the deeper horizons, in the tunnels, they are of much greater occurrence. Sometimes, a gradual transition is observed of carbonaceous shales into dark, almost black, carbonaceous limestone. All of the varieties described above are pierced by a network of calcitic, more rarely quartzitic, veinlets. All of the rocks of this strata are broken up by numerous fracturings of the cleavage, which frequently obscures the real latitudinal stratification; as a result of this, the shales are broken up at the time of disintegration into blocks or fine, acute-angled slabs. The carbonaceous limestones, which are developed among the sandstone-shale stratum, are represented in the form of a series of more or less broad strips with a trend identical to the sandstone-shale stratum. One of the most characteristic is the strip of limestones, which is well-traced along the axis of the basic anticline within the limits of the Dange Ravine and the southern margins of the Plavikovyy and Mednyy mountains and the Main ore field. Rocks of this strip are of compact structure, light-gray, frequently passing over into marble-like varieties. They are broken up by fractures, as a result of which an irregular form and various sizes of lumps and fragments are observed. Concerning the age of this limestone ridge within the limits of the southern part of the Plavikovyy mountain there exist conflicting data.

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Saukov, the first investigator, and later Smol'yaninov, on the basis of findings of fauna and fragments of rocks, referred these limestones to the Silurian period; the block character attributed to it the authors explained by the overthrust folding of the Silurian period from the side of the Ishme-tau.

Suloyev, taking into consideration the fauna material, represented exclusively by brachyopods, collected by the Smol'-yaninov party, and referring these limestones to the Lower "Vize" period, refuted the existence here of a block overthrust folding.

Farther to the north, within the limits of the northern margins of the Plavikovyy and Mednyy mountains, the Central cone and Northern field, is observed the second broad ridge of limestones, which are of exceptional interest, by virtue of the fact that the mineralization is coordinated to these limestones. The rocks of this ridge are of different color, most often ~~grayish~~ light-colored, of compact and schistous structure. The limestone ridge differs greatly from that described above both by the variability of its composition and also by the presence in it of seams of shales, frequently calcareous, with a gradual transition from one to the other. The variability of the composition of these limestones is especially clearly observed on the Mednyy and Plavikovyy mountains. The massive limestones here are characterized by a gradual change of the composition and structure transversely to their trend in a definite regular sequence: massive limestones -- schistous -- conglomerate-like and breccia-like. The most prevalent is a group of massive limestones which are poor in primary silicic acid and magnesium carbonate. At the contact with the ore breccia, the latter rather frequently pass over into

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siliceous (chertized) limestones. Limestones of this type are represented, basically, by two varieties: compact, massive, dark-gray, fine-grained limestones and schistous, yellowish-brown limestones. The breccia-like limestones are diffused to lesser degree than the two preceding varieties and are located for the most part in the form of thin (not more than several meters) seams in the shales or at the contact of the normal limestone with the shales.

According to the composition of the fragmental material, they are subdivided into simple (homogeneous) and complex limestones. The limestones are broken up by fractures and are pierced by calcitic veinlets of different thickness, which are concentrated chiefly near the ore breccia.

Regarding the age of the limestones of this ridge, according to the data of Suloyev, the latter was considered with the Lower Carboniferous. However, at the present time, after supplementary gathering of Silurian fauna in these limestones by Smol'yaninov, this question should be considered open until accurate data is accumulated which will permit arriving at a more correct and definite decision.

Thus, deposits of Paleozoic sedimentations are characterized by the complexity and variegation of their composition; among them, shallow, clayey, sandy, carbonaceous and conglomerate-like sedimentations acquire essential importance, with subordinate occurrence of the deeper-water phase -- of calcareous sedimentations. The general nature of these sedimentations and their fine interstratification bears witness to the considerable and frequent fluctuations of the level of the sea during the Paleozoic period.

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The sedimentary complex of rocks in the region of the deposit is intruded by vein formations of diabases of the stratified type, up to 4 meters thick; they are characterized by comparatively small extent, aphanitic or fine-grained structure, greenish color, frequently by amygdulose of calcite and "leysty" of plagioclase. These rocks are subdivided into diabase-porphyrites, diabasic almond rocks and chloritic-calcitic-chalcedonic diabases. They are encountered in many places in the Mednyy mountain and Central cone, amongst the sandstone-shale stratum. Contacts with sandstones and shales are clear. The zone of contact change of the rocks is not considerable; it is expressed in the occurrence of compression and pyritization both of the sandstone-shales and also of the diabases themselves.

The diabases of the first principal tunnel of the Mednyy mountain merit especial interest, where they are cut through by calcitic and pyritic veins. Intrusions of diabases preceded hydrothermal solutions (ore-formation) and, apparently, the phases of their development were sharply circumscribed. The age of the diabases and of the formation of the deposit most probably ~~should~~ should be referred to variscitic orogenesis. To the number of basic structural elements of the folded tectonics of the region pertains also the anticlinal folding, which enters the region of the deposit only through its northern wall. The southern wall of the fold is cut by the Khaydarkan valley. The axis of this fold, having basically a latitudinal trend, identical to the trend of the valley, is traced along the southern margins of the Plavikovyy mountain, the Kyzyl-tau, the Central cone and the Main ore field. In several sections it is complicated by fold-like bands, with a

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change of its general latitudinal trend to the north-east or north west. These changes of the trend are the result of the occurrence of a later phase of folding, created by pressure, which is oriented along an east-west line, that is, transversely to the trend of the predominant folding. On the other hand, in several sections, there was also a pitch of the axial line of the Khaydarkan fold, owing to which the strata of rocks sustained a sinking or rising. For the whole extent of the axis, the core of the fold is built up by shales and sandstones; the anticlinal part is represented by limestones, which slope rather smoothly and weakly to the north and south with angles of dip from 25 to 45 degrees. The northern wall of the basic anticline, in turn, is crumpled into a complex system of small folds of secondary order, among which stand out the synclines and anticlines with that same latitudinal trend. This secondary folding quickly and sharply alternates along the trend with isoclinal folds, which permits us to assume the presence in such points of those same folds, but already tilted to the south. The secondary folding possesses those same features that are characteristic of the basic fold. The latter is especially observed in the isoclinal fold of the brachyanticlinal type, which passes through the broad ridge of limestones and ore breccia of the Plavikovy and Mednyy mountains and the Central cone. The axis of this fold, which has a north-west trend in the middle part of the Mednyy mountain, as it advances to the west toward the Plavikovy mountain, is sharply changed to the southwest, with a dipping of the axis in that same direction. As it approaches the Central cone, the north-west trend of the axis turns to the east, sustaining again a dipping in the Yanguz-bulak-sau, but already to the east in direction. The existence of this anticlinal fold is reflected in several features of the morphology of the ore body and plays

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an essential role in an applied relation. Elements of pseudo cleavage, observed in the sedimentary complex rocks, ^{are} most strongly expressed in the shales and sandstones, most weakly in the limestones. This cleavage is oriented transversely to the trend of the basic folding in a south-north direction, or close to it, and with a varying dip to the east and west. Together with the folding, disjunctive dislocation also plays an essential role in the total tecto-genesis of the deposit. Within the limits of the Medny mountain, several types of dislocation are noted.

1. Fractures of faults and disintegration, corresponding to the north-west trend of the sedimentary strata 270 - 290 degrees and with a dip to the north-east $\angle 50$ - 80 degrees or to the south-west $\angle 60$ - 80 degrees.
2. Fractures of disintegration with a south-west trend 240 - 255 degrees and with a dip to the south-east $\angle 50$ degrees or to the north-west $\angle 60$ degrees.
3. Fractures of disintegration and dislocation, with a south-west trend 210 - 240 degrees and with a dip to the south-east $\angle 50$ degrees.
4. Dislocations, which have a north-west trend 315 - 350 degrees and a dip to the north-east $\angle 40$ degrees or to the north-west $\angle 45$ degrees.

The first two systems of fractures of disintegration and faults, running along the trend of the sedimentary strata and created by forces which acted in a latitudinal direction after the formation of the basic folding (of latitudinal direction),

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are observed for the most part along the contact of the limestones and the shales, more rarely in the limestones. The tectonics of these dislocations are extremely complex and are subdivided into a number of numerous parallel fractures and zones of breaking up and upthrusts. In addition, bending of the fractures along the trend and dip was observed frequently, more rarely with slope-like folds and with an uneven shattering of the zones. Corresponding with this, also, the ore formations which fill these fractures and zones of disintegration have a different character. The next system of fractures of disintegration and dislocation, which have a trend 210 -240 south-west, cuts the sedimentary strata of rocks almost transversely of the trend. This system of fractures, usually corresponding to the trend of the cleavage, is filled with veins and ore solutions (calcitic and quartzitic-fluoritic). These fractures-zones usually have little width and short length. In age, the large part of these dislocations preceded the so-called ore-less tectonics (that is, the system of fractures of dislocation 4 and 5), but was somewhat later than the dislocations which characterize the first two systems of fractures of disintegration. Later dislocations (types 4 and 5), which have an almost north-south trend, always intersect the fractures indicated above. These dislocations, coordinated for the most part to the ore breccia or the folds of the rocks, were accompanied by polished surfaces, mirrors of slide and scars on the ore breccia, and with zones of disintegration of the enclosing rocks. The age of these dislocations is various; judging by the fact that the fractures remained exposed, the large part of them are referred to post-ore tectonics, the appearance of which was in Alpine times. Thus, what has been stated shows that the dislocational processes,

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which formed the region and the Khaydarkan deposit, were formed by two orogenetical phases: 1) variscitic, subdivided into two sub-phases, and 2) Alpine (post-ore).

DESCRIPTION OF THE DEPOSIT

All investigators of the deposit noted the coordination of the mineralization to the contact of the limestones and shales. More rarely, the ore occurs in the limestone itself which has a massive structure and with sharply expressed fracturing, which also served as a means for the penetration of the ore solutions. Still more rarely, the mineralization is encountered in normal siliceous-argillaceous or carbonaceous-argillaceous shales, in the form of small veins and veinlets, without clear signs of their deep-seated change. However, most often of all, the process of change of the enclosing rocks took place so strongly that the limestones remained siliceous and rarely breccia-like, the shales -- silico-sericitic, usually purified and more rarely with variegated coloring.

The part of the deposit which has been studied extends along the trend from the Eastern ore field to the ravine of the Dange for 5,200 meters, with small breaks. But, judging by the signs of ore-bearing, observed to the west of the ravine of the Dange, the deposit is not restricted along the trend by this distance. The average trend of the deposit is latitudinal, that is, corresponding to the direction of the main folding and main system of fracturing, which are responsible for the zones of shattering of the rocks. Deviations are observed also, with a change in several sections of the latitudinal trend to the north-east or north-west. Regarding the extent of mineralization in depth, in

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this respect the ore body of the Mednyy mountain, which comprises the basis of the Khaydarkan deposit, at the present time is opened by tunnels in the eastern part of the mountain as far as the horizon 1,960 meters, that is, to a depth vertically of 170 meters.

In the Main ore field, the extent of mineralization is traced in depth only 24 meters in all; on the Plavikovyy mountain, to 218 meters, according to the variety of elevations of outcroppings of ore breccia. The thickness of mineralization in the individual ore fields also is extremely inconstant; for short distances along the trend and the dip it changes strongly; the veins swell at times to several tens of meters, at others taper down, forming narrowings to a scarcely noticeable streak, or disappear altogether. Among all of the ore fields the maximum thickness of the ore breccia again was observed on the Mednyy mountain. Here, on the surface, is registered the thickness of the ore breccia, which fluctuates from 10 to 54 meters (average thickness is 36 meters), which does not correspond completely with the decreased thicknesses observed in sub-surface workings.

On the Plavikovyy mountain, the thickness of the mineralized zone, on the average, was calculated at 8 meters, in the Main ore field at 11 meters. In form of occurrence, the deposit is referred to the type of irregular complex veins with sharply expressed sheet-like character. More rarely, lenticular cross veins, separated from the main ore trenches, were observed. Such apophyses are characterized by slight thickness, short extent and by the fact that they are encountered exclusively among the limestones and differ from the other type of ore (metasomatosiis type). Several of the veins under consideration possess characteristics

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this respect the ore body of the Mednyy mountain, which comprises the basis of the Khaydarkan deposit, at the present time is opened by tunnels in the eastern part of the mountain as far as the horizon 1,960 meters, that is, to a depth vertically of 170 meters.

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which are typical of pockets and druses and more rarely of saddle-shaped veins and "mushroom-shaped" formations. Comparing the broken up morphological types with the tectonic, we are led to the conclusion that the form of the ore body to a considerable degree is due to the development both of folding, that is, to the structural relations of the sedimentary rocks, and also of disjunctive dislocation, that is, fracturing and shattering of the rocks.

All of the ore formations of the deposit according to the nature of their formation and their mineral composition are subdivided into the following genetical types:

- | | | |
|---|---|---|
| 1. Ores of carbonization-metamorphic type | { | Breccias of friction and shattering
Breccias of metasomatism
Ore hornstones
Ore-less breccias and hornstones |
| 2. Ores of vein type | { | Quartzitic-pyritic-fluorspar formations
Quartzitic
Quartzitic-Fluorspar
Fluorspar
Quartzitic-mercuric-antimonite-fluorspar
Calcitic with ore components
Pure calcitic |
| 3. Re-deposited ores | | |

The breccias of friction and shattering occur at the contact of the shales and limestones in places of tectonic dislocation.

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The elements of occurrence of the breccia are similar to the elements of occurrence of the broken up zones of shattering and fracturing. The breccias for the most part have a gray color of various shadings, depending on the presence of ~~these or other~~ ^{various} components. In petrographical composition, the breccias are subdivided into simple breccias, consisting of one component, shale or hornstone, and complex breccias, the fragments of which are represented simultaneously by the two rocks indicated above. The simple breccia, cemented by quartz, fluorite, stibnite and cinnabar, which are encountered separately or together, are more prevalent than the complex breccia. The structure of the cement is cherty; often ~~(is observed)~~ the following arrangement of the minerals, depending on the order of their formation; along the edges is situated comb-like quartz; the central part is filled with irregular grains of fluorite, stibnite and cinnabar. The distribution of the ore components (fluorspar, cinnabar and stibnite) in the breccia is not uniform, with a strong fluctuation quantitatively. The size of the separate minerals composing the breccia is extremely small (they are fine and medium-grained); the crystals of stibnite stand out especially sometimes because of their size. ~~Proceeding~~ ^{Proceeding} from the fracture conception of breccia and ~~being present~~ ^{the fact of the presence of} in its cement concentrically ^{arranged} as a finely-banded, crustified zonality, it is possible to consider them as formations which developed only partially by way of replacement. Solutions, which freely-crystallized during the cementation of the fragmental material played the chief role in their formation. In mineral composition, this type of ore breccia is subdivided into the following ^a paragenetical series:

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Fragments of shale or hornstone	{	Quartz -- fluorite
		Quartz -- fluorite -- quartz
		Quartz -- fluorite -- quartz -- fluorite
		Quartz -- fluorite -- quartz -- fluorite
		--stibnite
		Quartz -- fluorite -- quartz -- fluorite
		-- cinnabar
		Quartz -- calcite -- cinnabar

The content of CaF_2 in the breccia of friction reaches 25 percent. The broken up type of ore is observed in many points of the Medny mountain and comprises an extremely significant part of the entire quantity of ores. Comparatively more rare^{ly}, it is encountered in the Main ore field and in the ravine of the Dange.

Breccias of metasomatoses are a transitional type of ore breccias of friction to hornstone. The mineralization developed here to a stronger degree than in the breccias of friction; it is possible that more favorable conditions for mineral formation existed here, owing to the presence of calcareous breccia, rock more easily displaced than the shales. Macroscopically, the breccia of metasomatoses ^{are} ~~is~~ an ore, for the most part, with fine-grained structure, more rarely with a breccia-like structure, and have a cherty habit. The ore is of gray color with various shadings, very hard, and produces lumps with edges that cut. Frequently, a deviation in the direction of normal breccia of friction is observed. In this case, the only difference is in the degree of erosion of the fragments, which is easily visible. The material composition of the breccia of metasomatoses differs little from the composition of the breccia of friction. The

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fragments of the shale, which are observed in the form of residual material, are cemented by quartz, fluorite, more rarely by stibnite and cinnabar, the quantities of which are found in various proportions. In the majority of cases quartz predominates; the content of sulfides is negligible. Frequently, fluoritic and fluoritic-stibnitic veins or pockets, which are its indissoluble part, are subordinated to this type of ore. Strictly speaking, this type of ore at the deposit does not have an individual importance and comprises an insignificant part of the following group -- of the ore hornstone.

The ore hornstone, geologically and genetically, comprises one whole with the breccia of metasomatism and may be separated from it only artificially. The formation of the ore hornstone is connected with the metasomatism of the limestone as a result of the penetration of the silico-ore solutions along the lines of tectonic dislocation of the zones of disintegration and fracturing. In addition, the hidden fracturing of the limestones, apparently, also played an essential role. This ore is represented by very fine-grained, in places almost cryptoclastic, minerals consisting of hornstone (aggregate of quartz) of dark-gray color with fine-grained impregnations of dark-violet, almost black, fluorite and of pyrite sometimes. In addition, the hornstone often contains pocket-like accumulations of white quartz and light-violet to colorless fluorite or veinlets of those same minerals. In the rarest cases, crystals of stibnite, red impregnations of cinnabar and calcite are observed. The distribution of the ore components in the ore is not uniform; together with the enriched sections, it is possible to see sections that are poor and even completely devoid of ore minerals (ore-less hornstone). On the chemical composition of the

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ore, typical for this group, representative analyses (in percent)
are given in Table 1 (Analyst B. Baskin).

Table 1

Components	Analysis I	Analysis II	Notes
Analysis of waste after reprocessing of acetic acid			
			Analysis I (Analyst B,
			Baskin - hornstone with
			dark-violet fluorite, scat-
			tered in the rock; antimony
SiO ₂	86.80	81.37	glance and cinnabar, none; taken
Fe ₂ O ₃	0.36	0.28	on the Plavikovsky mountain
Al ₂ O ₃	1.53	1.68	near the summit (western
TiO ₂	Traces	Traces	mineralized section)
CaO	7.36	10.16	Analysis II (Analyst B.
Loss during weak calcination	0.43	0.79	Baskin) - hornstone with
MgO	0.08	0.11	fluorite; sulfides in small
Acetic acid extract			
CaO	0.10	0.56	quantity. Brecciation not
MgO	Traces	0.04	seen. Taken from mineral-
Results of the calculation			
CaF ₂	10.25	14.15	ized section of Plavi-
CaCO ₃	0.16	1.00	kovy mountain. (more to the
			east of the first)

Ore-less breccias and hornstones yield significantly to the
ore breccia in extent. They are found in connection with the lime-
stones and display a number of gradual, imperceptible transitions to
them. As a consequence of the absence of a content of ore components,

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this group of rocks is only of interest from the point of view of the genesis of the deposit.

Among the vein formations the most important and most widespread are the quartzitic-fluorspar, fluorspar and quartzitic-mercuric-antimonic-fluorspar veins. The fluorspar in them is variously colored from almost black to colorless. As a consequence of the fact that the vein formations are thickly pierced, and in places even overflow the ore breccia, they are not an independent body, but one of the component parts of the breccia, which are formed under conditions of crystallization from solutions during the cementation of the fragmental material.

The next large group among the vein formations are the calcitic veins, which are not very thick, situated in the ore breccia, shales and more rarely in the limestones, which, according to mineral composition, are subdivided into monomineral calcitic veins and veins bearing a whole series of ore minerals (fluorite, cinnabar, barite, orpiment, realgar and others).

A distinguishing feature of the re-deposited ores is the circumstance that they occur not at the place of their formation, but are moved as a result of processes of disintegration of the ore breccia and the enclosing rocks. Re-deposited ores, judging by sporadic and random findings of them, clearly do not have any practical importance.

Among the genetical types of ore in question in the Khaydarkan deposit, the following main types of ore, which have practical significance, stand out.

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1. Coarsely-crystalline fluorite is light-colored and is encountered sometimes in monomineral veins. In the majority of cases, it produces large, irregular accumulations in the general cement of the breccia and hornstone, together with quartz, antimony glance and cinnabar. The color of this variety varies from pale-violet to crimson-colored, from pale green to colorless. N. A. Smol'-yaninov cites the following analysis (in percent) of this fluorite, carried out by the analyst Khovanskiy:

Ca	51.30
Bi ^a	Not detected
F	48.53
S	Not detected
CO ₂	Not detected
SiO ₂	0.13
Fe ₂ O ₃	0.02
Al ₂ O ₃	0.16
H ₂ O at 105 degrees	0.02
Loss during calcination	0.02
	100.08
F, computed as Ca	48.66
Total, with F computed as Ca	100.31

As a consequence of the low content of sulfides, and even their absence, as a harmful admixture for the fluorspar, this ore may have a completely independent importance for fluorite. This sort of ore is rather often observed on the Plavikovyy and Mednyy

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mountains. The content of CaF_2 reaches up to 50 percent.

2. Finely-crystalline, dark-violet, sometimes almost black, fluorite. It does not form accumulations, but is an impregnated, diffused ore. In addition, it takes part in the structure of cockades. The components of the ore are shales (fragments), hornstone, quartz, antimony glance, cinnabar, calcite and others. Such an ore is observed in numerous points of the Medny mountain, more rarely in the Plavikovyy mountain, and comprises an extremely significant part of the whole quantity of the ores. The content of CaF_2 reaches 20 - 25 percent, rarely more. This type of ore, on the basis of its complex mineralogical composition pertains to the complex type. Therefore, the extraction of this sort of ore must be promoted in the plan for the complex utilization of all the components of the ore.

N. A. Smol'yaninov cites the following chemical analysis (in percent) of this variety of fluorite; the analysis was conducted by Analyst Khovanskiy:

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Ca	51.25
F	49.53
SiO ₂	0.09
SO ₃	Not detected
BaO	Not detected
Fe ₂ O ₃	0.01
Al ₂ O ₃	0.03
H ₂ O at 105 degrees	0.07
Loss during calcination	0.22
CO ₂	Not detected
	101.20
F, computed as Ca	48.62
Total with F. computed as Ca	100.29

3. Finely-crystalline fluorite. Components of the ore are hornstone, quartz, calcite, barite, a little cinnabar and antimony glance. The content of CaF₂ reaches up to 10 percent. This ore has a limited diffusion and is encountered chiefly in the region of the Main ore field. As a consequence of the low content of the CaF₂ the reserves of which are negligible, this ore has conditional importance for fluorite, being in large degree an ore for mercury. The mineral composition of the primary ores of the Khaydarkan deposit is not distinguished by large variety; basically, it is composed of four mineral components - quartz, fluorspar, antimony and cinnabar. Among the secondary minerals, which have a primary character, there are pyrite, calcite, barite, nacrite, realgar, orpiment, aragonite, fematinitite, chalcopryrite, and

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native gold. A mineral is present also, similar to anatase. Secondary, neogenic minerals also are not distinguished by a variety of different forms. Iron hat in its usual representation is completely absent; secondary minerals, in the majority of cases in negligible quantities, cover the walls of the fractures or else displace the separate minerals in the primary ores. Among the minerals characterizing the zone of oxidation, sulfur, goethite, limonite, psilomelane, valentinite, antimony ocher, malachite, azurite, chrysocolla, gypsum, jarosite and turanite were encountered. The minerals of the zone of cementation in the given deposit are represented by only covellite, findings of which are not characteristic and are rare. The formation of the deposit and the genesis of the ascending ("gipogenny") [hypogeny] hot solutions is found in close genetical connection, on the one hand, with tecto-genesis, which developed in the formation of complex folding and disjunctive dislocations, and on the other, undoubtedly, with the magmatic furnace which exists at a depth and is not opened by erosion, appearing beyond the limits of the deposit in the presence of basic and acid intrusive rocks and directly on them, a vein of diabases. Concerning the nature of the ore solutions, it is necessary to recognize their complexity and mobility. Saukov assumes the presence in them of alkaline silicon salt, silico-hydrogen fluoride, and hydrofluoric acid, and also alkaline sulfo salts, antimonite acid and complex compounds of the type $HgO.K_2O$. It is not clear if the solutions were complex from the very beginning and their composition changed depending on the temperature, or whether a gradual change took place in the solutions with time. In any case, the minerals were not precipitated

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simultaneously during the process of ore-formation, but were crystallized in a sequential change, which is easily seen in the enclosed table of mineral-formation. In the beginning phase of ore formation, when the aqueous solutions are characterized by an abundance of silicic acid with the weak assistance of hydrogen sulfide and hydrogen fluoride thermal springs, the formation takes place of numerous quartzitic-pyritic, quartzitic and, finally, quartzitic-fluoritic veins. In the beginning of the second phase, at the time of the noticeable impoverishment of the solutions of silicic acid and during the increase of the content of hydrogen fluoride, the crystallization takes place of comb-shaped quartz of the first generation, dark-violet fluorspar and the formation of quartzitic - fluorspar ore (hornstone) by means of metasomatism.

No.	Minerals	Silico-	Silico-fluoro-	Carbonate [Hypergene]
		sulfide Phase	Sulfide Phase	"Cipergen" Phase
1	Pyrite		Rhomboïd	
2	Chalcopyrite		Chert Chalcedony	
		Compact	Comb-like	
3	Quartz		Dark-violet Rose and Colorless	
4	Fluorite			
5	Stibnite			

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6	Anatase		
7	Cinnabar		Columnar
		Rhomboid	Rhomboid-
8	Calcite		
9	Barite		
10	Macrite		
11	Strontianite		
12	Goethite		
13	Realgar		
14	Orpiment		
15	Aragonite		
16	Sulfur		
17	Pamatinite		
18	Valentinite		
19	Limonite		
20	Stibnite		
21	Melanterite		
22	Covellite		
23	Malachite		
24	Azurite		
25	Chrysocolla		
26	Psilomelane		
27	Gypsum		

Figure 1. Genetical table of mineral-formation of Khaydarkan.

The following temporary increase of silicic acid, which is

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seen in the formation of comb-like quartz of the second generation, again alternated with the hydrogen fluoride thermal springs, with the emergence of sulfide solutions, which somewhat preceded them, with which is connected the crystallization of the antimony glance and cinnabar. The end of the second and third phases, as a consequence of the lowering of the temperature, is characterized by the emergence of carbonic acid and sulfuric acid solutions, which yield calcite, barite, and sulfurous-arsenous minerals. With the end of the third hydrothermal phase, it is necessary to consider the crystallization of aragonite, after which followed the fourth "gipergeren" phase, which is expressed in the formation of the secondary minerals of the deposit (Figure 1). The broken up association of minerals and their close genetical connection with a vein mineral - the nacrite shows clearly that in the time of their formation a comparatively high temperature and low pressure predominated, corresponding to the surface zone of the crust, which enables us to refer the khaydarkan deposit to the type of epithermal, complex deposits.

In spite of the fact that the Khaydarkan deposit was discovered in 1926 and is one of the largest in the Union both in reserves of mercury and also in fluorspar, up to the present time there is no adequate data for the calculation of its industrial reserves, in particular with respect to the fluorspar. The latter is explained by the fact that sections of the deposit which were prospected in the beginning (up to 1931) are not characterized by a high content of fluorspar (the Main field) and were considered only as deposits of cinnabar. Only with the transfer of operations to the Mednyy mountain, where the content of fluorspar is considerable, did the deposit acquire importance as a mercury-anti-

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mony-fluorspar complex. The calculation of the reserves, carried out by O. M. Kaminskiy on the first of July, 1933, produces for the Mednyy mountain; fluorspar, with an average content of 11.3 percent, 1,063,000 tons, or, according to categories for fluorspar - 185,795 tons in category B and 877,130 tons in category C₁.

Previous calculations gave comparatively large amounts in all items of mineral resources. Thus, with respect to fluorspar, the first calculations of Saukov produced for the Mednyy mountain 2,640,000 tons, with an average content of CaF₂ of 21.8 percent; calculations carried out later by M. A. Smol'yaninov (1931) gave 1,625,000 tons, with an average content of CaF₂ of 12.5 percent, and, finally, the calculations of A. I. Suloyev gave 1,632,000 tons, with an average content of CaF₂ of 19 percent.

In the analysis of the reserves, from the point of view of the possibility of planning an undertaking, it is necessary to have in view a number of essential corrections, which can change their figure both on the side of an increase and also on the side of a decrease, as a consequence of the vagueness of the form of the ore body in depth, its variability and changeability of ~~size~~ thickness along the dip and trend and the unevenness of distribution of mineralization (together with sections that are deficient or almost entirely ore-less, sections are encountered with contents of CaF₂ up to 50 percent). However, the reserves of fluorspar are by no means exhausted by the figures cited; if, actually, the mineralization is not confined to the horizon from which the calculation was carried out, and if the fluorspar

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of the remaining fields is taken into consideration, then the figures on the reserves must be increased considerably. Economic-geographical conditions of Khaydarkan are completely favorable for the development here of a large-scale enterprise. The location of the deposit in a huge valley with a grassy covering, together with favorable climatic conditions, affords the possibility for organizing its livestock and grain economy. The enterprise can be completely assured of manpower from the local population, principally from the nearby villages of Sokh, Okhna and others. The transport problem can be considered solved, basically, at least for the time being, inasmuch as the whole route from the mine to the town of Fergan is served by auto transport. Hydrographical conditions, also, although in lesser degree, are favorable. The considerable water resources of Shakhimardan and Sokh can serve as the basis for the construction of an electrical power center. It is possible to guarantee water for a concentration plant because of the Allaudin and Gauyan rivers, which pass through near the southern edge of the valley, 7 - 8 kilometers from the deposit.

SECONDARY FLUORSPAR DEPOSITS IN THE KIRGIZ SSR

A. L. Ponomarev

Besides the Khaydarkan and other antimony-mercury deposits of fluorspar, a number of points in the Kirgiz SSR are known with outcroppings of fluorspar, located chiefly in the eastern part of the republic. To the number of such recorded, but little known points is referred the deposit of fluorspar along the Kurtka River, discovered in 1915 by V. N. Ryabinin.

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It is located approximately 80 kilometers to the west of the town of Maryn in the Kiche-korgo Ravine, which opens into the Kurtka River on the right side, the Kurtka being a tributary of the Naryn River. According to the data of V. N. Ryabinin, a vein of fluorspar passes through here in the carbonaceous limestones, 4 - 6 meters thick, along a trend which he did not trace. In the summer of 1935, this deposit was visited by A. P. Burov. According to the data of the letter, the fluorspar mineralization is a saddleshaped vein, coordinated to the scarf of a small anticlinal folding. The amounts of mineralization are small and confined by the extent of the vein up to 40 meters. The composition of the ore is characterized by the presence of fluorspar and quartz, which form a quartzitic-fluorspar rock, galenite, calcite and fragments of enclosing rocks. The fluorspar frequently forms independent formations, which comprise 30 - 40 percent of the whole contents of the ore body. The content of CaF_2 in the quartzitic-fluorspar rock fluctuates within the limits of 25 - 65 percent. The reserves of the deposit are roughly estimated by A. P. Burov at 40 - 50 thousand tons of ore, with an average content of CaF_2 of 60 - 70 percent. By virtue of the unfavorable economical conditions and the remoteness of the deposit from transportation routes, it does not merit industrial interest at the present time.

Still less known is the May-turda deposit, located near a similar pass in the central part of the Kara-kattytau Range, also in the region of the town of Naryn. This deposit was discovered in 1914 by K. N. Argentov, by whom is pointed out a vein of color-less and violet fluorspar, 4 meters thick, passing through the shales. In the summer of 1935, A. P. Burov

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attempted to examine the deposit, which, however, in spite of intensified prospecting, he was unable to locate.

Kassin points out also the ^{finding} of several small veins of fluorite, which pass through at the contact of the limestones and granites along the Cherkun-bulak River in the basin of Lake Isayk-Kul'.

Rather thick veins of fluorspar in the upper parts of the Kara-kunus River, approximately 100 kilometers to the east of the city of Frunze, are known as a result of the operations of A. A. Amiraslanov.

It is completely certain that all of this region, which gravitates, in the broad sense of the term, toward Lake Issyk-kul', is of great interest in the sense of the possibility of finding here new, large, industrial deposits of fluorspar.

TADZHIK SSR

R. V. Getseva and S. Z. Shifrin

TAKOB DEPOSIT

Introduction

The Takob lead-fluorite deposit is found in the central part of the Tadzhik SSR on the southern slope of the Gissar Range, 48 kilometers to the north of the city and station of Stalinabad, approximately at 38 degrees 50 minutes N. and 68 degrees 55 minutes E. (of Greenwich). The deposit is located on the bank of the left tributary of the Varzob River, which bears the name Takob River in its upper and middle course.

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The village of Takob, 1 kilometer above along the course of the Takob River, and the village of Diamalik, 3 kilometers from the deposit on the Diamalik River, which is the Dzhamagatsk center, are the nearest populated points to the deposit.

Historical Study of the Deposit

In the Takob deposit, the ancient workings in the upper side of the ore body were preserved. The object of the extraction was lead glance.

Judging by the nature of the workings and the method of work by "pozhog", the exploitation of the deposit is referred to the period of the opening of the ancient "sogdiysk"-Arabian developments for lead-silver ores in the Maveranadra, which pertains to the X-XII centuries, or, according to another version, derived from the local inhabitants, the minings of lead ("konisafet", that is, white ore) on the Takob River are referred to the early period of the emirate, when "lead tribute" existed, which the Dekhane paid by nature.

Later, these mines seemed to have been forgotten for a long time. In 1932, this Takob deposit [40] was registered and set apart as deserving attention as a source of lead by the Gissar geo-chemical party, under the direction of Ye. D. Polyakov, which was investigating this and other deposits of mineral resources.

In 1933, preliminary prospecting operations were set up by the party of the TPE, under G. Mikhaylov, at the Takob de-

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posit; the prospecting showed, however, that the deposit was not favorable for exploitation for lead, inasmuch as there were insufficient reserves of the metal. At the same time, according to the instruction of Professor V. I. Luchitskiy, attention was given to the deposit as a source of fluorspar [86], in view of the large reserves of almost pure fluorspar.

The following year, a large geological-prospecting expedition under the direction of S. Z. Shifrin was organized on assignment of Glavnetmet by the Institute of Mineral Resources, together with TPE; during the season of 1934, the party carried out a full-scale study of the deposit. These operations showed that the Takob deposit is one of the largest deposits in Central Asia and unconditionally has industrial importance as a fluorspar deposit, with the possibility of a complex side recovery of lead and silver. The excellent results of the investigation showed the richness of the Takob ore, which affords the possibility of recovering from it the conditional fluorspar. The present article is based to a considerable extent on the report concerning the operations of this expedition, which exhaustively throws light both on the deposit itself and also on the region adjacent to it [93].

In 1935, operations on the utilization of the Takob deposit were continued. Together with continuation of the geological prospecting operations, performed by the Central Asian Geological Trust, preparation of it for exploitation was begun by the Takobrudstroy, especially created for this purpose by Glavnetmet. Simultaneously, planning operations are being car-

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ried on. On the operations of 1935 there is a manuscript report confirming the interpretation both of the geological and also the prospecting materials of the expedition of the IMS, and supplementing it in the part of the study of the deposit on the depth by means of sinking of bore holes [88].

Relief and Hydrography of the Region

The region of the Takob deposit is typical mountain country with a highly dissected relief and relative elevations up to 900 - 1000 meters. The form of the relief is comparatively dependent on the nature of the rocks which compose the region.

Most difficult of access are the sections built up by porphyries with abrupt, craggy sides and numerous pointed summits.

The relief of the granite massifs possesses softer forms; the slopes are highly smoothed down and littered with fine gravel. Sections, built up by sedimentary rocks of Mesozoic age, are distinguished by the rolling character of the relief.

The region is covered by a rather dense, erosional network with precipitous mountain streams. The valleys of the rivers, in particular the Takob River, are framed by 2 - 3 sharply expressed terraces, which bears witness to the recent rejuvenation of the relief.

The lower river terrace, which is 100 - 150 meters wide on the left bank of the Takob River, is a series of terraces convenient for construction, which the Takobrudstroy has taken ad-

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vantage of.

The second terrace, also built up by river sedimentation and deluvium, is covered with young crops and pasture grounds.

The typical mountain Takob River changes the steepness of the slope from 120 meters per 1 kilometer in its upper course to 40 meters in its lower and middle course. Here, small tributaries open into it from the left, the Dada-i-shura River, Bezymyan, Plavikov brooks, and a number of springs, which are numerous in this section.

In the region and, in particular, in the section directly adjoining the deposit, springs with good drinking water are often encounteredⁿ at various heights.

The relatively high location of the valley of the Takob River and the proximity of the snowy summits strongly mitigate the sultry climate of the region.

The population is rather dense for such a mountainous region with passes which are difficult to negotiate, with villages situated 3 - 5 kilometers from each other.

Geology of the Region

The region of the Takob River and the area adjoining it are built up by rocks of various age, from lower and middle Paleozoic to the upper horizons of the Mesozoic (see the stratigraphic scheme); crystalline rocks predominate, for the most part acid intrusive and effusive rocks.

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The age of the granite intrusion is the most reliable, inasmuch as in the regions adjacent to Takob these granites break the Paleozoic folds and the Upper Paleozoic deposits, and, on the other hand, they transgressively are covered by the Rhaetian and Lower Cretaceous deposits; as a consequence, their age is Upper Paleozoic.

Operations in 1934 have established that among the whole complex of eruptive rocks the Upper Paleozoic are the youngest and that there is a whole series of more ancient porphyrites.

These latter rocks, together with metamorphic formations, developed 6-7 kilometers to the north of the Takob River (see the survey geological map of the region), are united with respect to age as "Paleozoic, not determined closer". In addition, the metamorphic stratum and effusive plagioclastic porphyrites are more ancient than the granodioritic, microgranitic and quartzitic rocks.

The porphyrites are connected with the development of Caledonian folding.

Regarding the acid porphyritic rocks, stratigraphically they are located between the eruption of porphyrites and the Upper Paleozoic intrusions of granites. Inasmuch as there are no firm indications either for referring them to Caledonian time or for their connection with variscitic orogenesis, the question of their age remains open. These rocks play an extremely essential role in the structure of the Takob region,

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composing all of its central part between the valley of the Takob River and the Dara-i-safet River.

"Paleozoic, not determined closer"

The most ancient metamorphic stratum, with respect to age, consisting of complexly dislocated, marbled limestones and shales, appears only in the upper parts of the Diamalik River in the form of small residual mountains, covered with granite; the latter caused an intensive metamorphization of the limestones, with the formation at the contact of typical skarns. Further, to the north, the limestones and shales are more developed; the mountain passes of the Gissar Range are composed of them.

Not playing any role in the structure of the Takob region, this stratum has an importance stratigraphical significance, inasmuch as it is widely known in the Seravshano-Gissar system under the name "Paleozoic, not determined closer", with age limits from the Upper Silurian to the Upper Paleozoic.

In the Takob region, they must not be younger than Middle Paleozoic.

With respect to age, close to the Paleozoic metamorphic stratum stand eruptions of porphyritic and tuffaceous lava. In the Takob region, these rocks cover ~~large~~^{small} sections, stretching in a north-east direction, and sometimes the enclosing dikes of quartzitic porphyres. The porphyrites contain, as impregnations only, plagioclase (andesine No. 35 - 45). The basic mass of them is hyalopilitic, pilotaxitic and orthophyric. Usually these rocks are subjected to an intensive greenstone change; at the contact with the granite intrusion they are

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Stratigraphic Chart of the Takob Region

	Time	Geological Process	Notes
	(1)	(2)	(3)
Cenozoic	Quaternary	Denudation and formation of glaciers	
	Period	and alluvial sedimentations	
	Tertiary	Main phase of Alpine orogeny	
	Period	Further accumulation of maritime sedimentation	In the Takob region, the Tertiary deposits are entirely destroyed by erosion.
Mesozoic	Upper	Deepening of the sea basin, which	
	Cretaceous	deposited limestones with numerous: <u>Ostrea</u> , <u>Exogira</u> , <u>Trigonia</u> , <u>Pecten</u> , <u>Plicatula</u> , <u>Turritella</u> , etc.	
	Lower	Broad transgression of the sea with	
	Cretaceous	alternation of lagoon and continental conditions, accompanied by deposit of a stratum of alternating layers of conglomerates, sandstones and clays, in the upper part with a content of badly preserved remains of pelecypoda, gastropoda, bryozoa, and echinoidea	
		Protracted denudation	
		Ore process	

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	(1)	(2)	(3)
Paleozoic	Upper	Formation of lamprophyritic, pegmatitic and quartzitic veins	
	Paleozoic	Thick variscitic intrusion of granite magma in the form of batholite	
		Formation of veins of porphyro-like aplite (al'sbakhit)	
		Hypabyssal intrusion of granodioritic, microgranitic and quartzitic porphyries	
	"Paleozoic not determined closer"	Eruption of plagioclastic porphyrites	
		Deposit of limestones and clays	Under the influence of the granite intrusion, the rocks are transformed into marble and shales

chertized. These eruptions are connected with the pre-variscitic movements of the crust.

Next in stratigraphical position in the chart of the geological structure of the Takob region is the group of porphyritic rocks of acid composition, still less definite with respect to age.

In the aggregate, these rocks form a hypabyssal body, partially, apparently, coming into contact with the earth's surface. This intrusion displays distinct signs of zonality, while the deepest

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rocks appear to be granodiorite-porphyries. The microgranitic porphyries are adjacent to them and, finally, the quartzitic porphyries, which were partially solidified on the surface. These rocks compose the central part of the region, lying directly under the Mesozoic deposits. In the south -- near the latitude of the confluence of the Takob and Diamalik Rivers -- the porphyries are burst open by the younger granite intrusion, which produces at the contact with it a noticeable chertizing, and in the northern part of the region they are cut off by a powerful Alpine overthrust of granites and metamorphic rocks. Derivatives of this intrusion are the veins of porphyry-like aplites (al'sbakhity). As has already been indicated, there is no data for an opinion regarding the connection of this intrusion with the definite orogenetical cycle.

With respect to petrography, the rocks of this intrusion are close together, representing a more essential difference in regard to structure. Thus, the granodioritic porphyries are distinguished by a characteristic granitic-porphyritic structure, where the phenocrysts are distinguished according to their sizes from the granitic basic mass of rock.

Among the phenocrysts and in the basic mass, albite-oligoclase predominates, considerably sericitized, quartz in lesser quantity, and rarely contains potash feldspar. Biotite and now and again hornblende are present as a dark-colored component.

The microgranitic porphyries are distinguished by fine-grained structure and the absence of a macroscopically expressed

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porphyritic structure. Those same phenocrysts of microscopical sizes occupy more than 50 percent of the rock, as also in the granodioritic porphyries. The microgranitic basic mass is richer in quartz and poorer in biotite in comparison with the phenocrysts.

The quartzitic porphyries are characterized by a euphorphyritic structure with a fine-grained, reaching a felsitic, basic mass and phenocrysts of predominating quartz and feldspar and chiefly of plagioclase (not yielding to determination).

Upper Paleozoic

The more powerful intrusive process, the products of which were biotitic granites and the syenites, which are not very widespread, the aplite-like granites and granodiorites which are connected with them, is correlated to the Upper Paleozoic in the Takob region. The granites form a large batholite, which is cut in its northern part by the Takob River. The granite massif, which is found in the upper parts of the Diamalik River, comprises part of that same intrusion, later considerably raised and thrust to the cap rocks by the Khadzhaobigarmask dislocation.

The Takob massif and the southern part of the northern massif are built up, basically, by leucocratic biotitic granites, generally of medium-grained structure. Besides the characteristic combination, quartz--potash feldspar--plagioclase (oligoclase), biotite is present in small quantities.

The structure is granitic; in individual sections there are pegmatitic and granulitic concretions. The high content of SiO_2 and the exceptionally low content of CaO and MgO justify its

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inclusion in the leucocratic variety.

The aplite-like muscovite granites and micaceous syenites are present as phase formations of the biotitic granites.

The hornblende-biotitic granodiorites make up the northern part of the upper granitic massif, directly adjoining the Paleozoic metamorphic stratum. The formation of these rocks is due to the assimilation of the granitic magma of the limestones from their covering.

Like any hybrid rocks, the granodiorites have a variable mineralogical characteristic, principally in the quantitative proportion of the minerals entering into them. Plagioclase sharply predominates over the remaining minerals; potash feldspar, quartz (from 4 to 15 percent) and biotite are always present, and frequently, too, amphibole and augite.

The granodiorites are characterized further by the processes of metamorphism which entered in, chiefly of an auto-metamorphical nature.

With the granitic intrusion is connected the formation of lamprophyric, aplitic, pegmatitic and quartzitic veins, occurring principally in the marginal part of the batholite, with a small entry into the covering. Especially broadly developed are the pegmatite veins of zonal structure, with the largest development of phase E of the pegmatitic process (according to Fersman). Such veins, usually of gigantic sizes, frequently are built up of pure quartz, with narrow pegmatitic and aplitic casings. Sometimes they

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mineralize the enclosing rocks with formations of fluorite in them.

Mesozoic

Mesozoic deposits, characteristic of the Lower and Upper Cretaceous period, cover a considerable part of the region located to the north of the Takob River, being squeezed from the north and south between two large Alpine overthrusts; they occur almost horizontally to the eroded surface of the Paleozoic porphyries, with a general sloping dip to the north of the whole stratum and are built up by a number of small, broad brachyfolids.

Basically, basal conglomerates -- traces of abrasive action of the Lower Cretaceous sea -- occur with the whole Cretaceous stratum.

In the lower horizons of the Lower Cretaceous, coarsely fragmental and sandy deposits are developed; in the upper horizons, limestones emerge, with poorly preserved impressions of marine fauna.

The composition of the stratum is distinguished by considerable fluctuations, especially in the lower parts of the layer. The upper horizons of the Lower Cretaceous in all parts of the region are expressed by gray, sandy limestones, which contain remains of oysters and other pelecypoda, which were not determined closer, frequently bryozoa and remains of echinoidea.

Being based on a gradual lithological transition of these horizons to oolitic limestones, with Senoman and Turonian fauna, and on the similarity of the argillaceous-sandy stratum of the

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Takob region with the Lower Cretaceous rocks of the southern and southwestern slopes of the Gissar Range, its age is determined as Lower Cretaceous. The overall thickness of the Lower Cretaceous deposits is nearly 300 meters.

Oolitic and shell limestones of the Upper Cretaceous, characterized as Senoman and Turonian with respect to the fauna, are the youngest rocks originally occurring in the Takob region, and at the present time are considerably deteriorated by erosion. The apparent thickness of them in all is nearly 50 - 75 meters.

With respect to geological structure, the region of the Takob deposit, in its main features, has been determined as of variscitic orogenesis, which imparted to it the character of a folded region. The Alpine mountain-forming movements later complicated the structure of the region, owing to the thrusting up of the more ancient formations onto the correspondingly younger ones.

At the present time, the pre-variscitic movements remain obscure for all of Central Asia. A number of facts indicate the presence of Caledonian folding in the Alay folded system. In the Takob region, apparently, a formation of plagioclastic porphyrites is connected with it, and, possibly, an intrusion of acid porphyritic rocks.

Variscitic orogenesis reached its maximum in the Upper Paleozoic; to this period is referred the formation of the principal folded structures.

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The Takob region is located in the northern wall of a large anticlinal fold of almost latitudinal trend, with the sweep of the walls embracing the whole section of the southern slope of the Gissar Range. In the eroded core of this anticline occurs the Odzhyksko-Takob granitic batholite, to the marginal part of which is coordinated the deposit of fluorspar.

Relative to it are located, symmetrically, porphyritic rocks and the metamorphic stratum, which drop rather sharply to the sides of the batholite.

After the formation of the folded forms, stresses developed greatly, connected with the phase of expansion of the crust. They were discharged in the formation of the numerous faults and fractures, with traces of mineralization later, which are traced both among the granites and also among the more ancient rocks. The direction of the radial dislocations, spatially, ranged from southwest 260 degrees to northwest 330 degrees, sometimes northeast 10 - 40 degrees.

Their development in time was, apparently, rather lengthy, inasmuch as in the region there are definite indications of the existence of several systems of fractures, which did not occur simultaneously according to age, which cut one another. Also, the superimposing of younger dislocations on more ancient dislocations in the former directions sometimes is observed.

The character of certain of the youngest and usually small dislocations sometimes produces the impression of a dislocation, associated with the fold formation and thus developed into the

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younger -- Alpine -- phase of orogenesis.

This, in considerably less degree, relates to the large, usually more ancient dislocations with distinct signs of radial character and with the presence of diverse mineralization, including ore deposit. Their common feature is the linear arrangement with a sufficiently expressed trend and sharp angle of dip.

Thus, with the comparatively ancient faulted tectonics of the region is clearly connected the dislocation with the direction northwest from 270 to 320 degrees, sometimes 330 degrees. Within these limits among all of the Paleozoic rocks of the region, sufficiently expressed zones are detected, which are characterized by crumpling, disintegration and by the development of a diverse mineralization activity, such as chloritization, sericitization, kaolinization and quartzitization. The trend of almost all of the hydrothermal quartzitic veins is approximately the same.

The Takob ore vein is coordinated to this same direction.

Besides these large dislocations, numerous smaller dislocations, sometimes cutting the former, are stated in the region. Frequently, such dislocations, during frequent recurrence, produce systems of step-like dislocations.

On the basis of the materials for study of the Takob deposit, it can be established that the movements repeatedly were renewed, both at the moment of formation of the ore body and also in the post-ore phase.

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The further formation of the geological structure of the region was completed in the epoch of Alpine orogenesis. The Cretaceous rocks were collected in a number of sloping folds with a trend close to the latitudinal. Fold formation was accompanied by occurrences of powerful overthrusts, which have a regional character for all of the Gissar Range.

In the Takob region, two large overthrusts are detected, shearing from the north and south the cover of Cretaceous deposits and dividing the region into three large tectonic units: the northern granitic horst, southern horst of porphyries and granite, and the central depression zone, where on the Paleozoic crystalline base transgressively occur the remains of the erosion of Mesozoic sedimentation.

The northern Khadzhaobigarma overthrust possesses, evidently, a considerable range, in any case not less than 1000 meters. This overthrust extends to the north of the Takob deposit, where discharges of the Khadzha-obi-garma hot mineral springs on the right bank of the Barzob River, with a temperature of nearly 87 degrees, are connected with it.

The southern overthrust, first recorded by the expedition of the IMS in 1934, also passes through the whole Takob region to the latitude of the Kasan River, through the upper parts of the Takob River. Its range is considerably less in comparison with the Khadzhaobigarma overthrust. Dislocations, born by the southern overthrust to the bed of rocks in the zone adjacent to it, are expressed in a sharp fold to the north of the heads of the Lower

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Cretaceous strata and in the "kataklasirovaniye" of the porphyries thrust up on the Cretaceous strata. The overthrusting takes place on the curve of the surface, sometimes more, other times less sharply falling to the south. In the western part of the region the angle of dip of the surface amounts to nearly 30 degrees, in the central part of the region it amounts to nearly 75 degrees, and in the eastern part nearly 40 degrees to the south.

Inasmuch as the dip of the overthrust in the central part of the region is sufficiently sharp (see the cross section), a quick cutting of the Takob fluorspar vein by it should not be feared, in any case of such a nature as would be reflected in the practical significance of the deposit.

GEOLOGY AND TECTONICS OF THE DEPOSIT

The Takob deposit of fluorspar is coordinated to the northern marginal part of a large granitic batholite, which joins the divide between the Takob and Obiodzhuk Rivers.

The region of the deposit is a number of spurs running out to the north from this divide and gradually descending to the riverbed of the Takob River. The granites are strongly crumbled with the formation of thick piles of eluvial and deluvial material, which are heaped up in the deep ravines, alternating with sloping "grivka". The latter, near the valley of the Takob River, dip under the river terraces adjacent to them; the "grivka" consist of an upper trunk of granitic eluvia and a lower river "grivka", strewn with a great number of well-rolled pebbles.

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The ore body, which has the form of a normal vein, passes through among the leucocratic biotitic granites, chiefly of medium-grained structure, which contain in themselves separate vein-like bodies of micaceous syenite and muscovitic, aplitic granite. The pegmatite, aplite and quartz veins are well developed, the main mass of which trend to the northeast, close to the meridional points of the compass.

The granites are exceptionally ready to yield to mechanical disintegration (disaggregation), changing them at depths of many tens of meters into a highly broken up rock, accessible for the circulation of ground waters. This circumstance highly complicates the technique of core drilling.

At a distance of 100 - 125 meters to the north of the deposit, the granites are found in contact with the more ancient quartzitic porphyries.

Tectonic stresses, repeatedly recurring both in the course of the ore process and also into the post-ore phase, imposed a complex imprint on the ore body, extremely hampering the restoration of the original structure and the true interrelationship of its component parts.

The junction of two intensively developed orogenetical phases (variscite and Alpine) in this section, complicates to a significant degree both the study of the tectonic processes and also the restoration of their historical sequence; inasmuch as it does not seem possible always to determine the geological age of individual systems of dislocation, the ore process was chosen

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as a criterion for the classification of them.

In accordance with this, A. V. Kopeliovich [93] divides all of the numerous and complex tectonic elements of the deposit into three groups: pre-ore tectonics, intra-ore and post-ore.

Pre-ore tectonics. Among the numerous, distinct pre-ore tectonic dislocations in the region of the deposit, two systems have the greatest significance: with a trend northwest 285 to 305 degrees and with a dip to the southwest $\angle$ 70 - 80 degrees and with a trend northwest 320 to 330 degrees and with a dip to the southwest $\angle$ 70 degrees.

The first appeared in the formation of a large fracture, which served subsequently as a means for the penetration and localization of the ore solutions.

Here, we are dealing with a large fault which was accompanied by the formation of characteristic, in the first stage, loose, fault breccia from the surrounding granites, later cemented by the thermal solutions.

The nature of the filling in of fault fracture indicates the presence in it of free space, which facilitated the circulation of the solutions.

It is probable that simultaneously with the main ore fracture, smaller fractures developed, running parallel to it and subsequently filled also with fluorspar.

The second system of dislocations or pre-ore age, with a

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trend northwest 320 - 330 degrees and a dip to the southwest $\angle$ 70 degrees, is encountered rather often in the form of veinlets sometimes and at a considerable distance from the ore body. To this refers the abundant, fine, almost hair-like, fracturing of that same direction in the under side of the ore body, filled with "korochki" of fluorite.

The system 320 - 330 degrees frequently bears traces of dislocation, when it is possible to observe in the veinlets small, well-rolled granitic breccia. In their turn, the dislocations described above of the system 285 - 305 degrees give way to it, although the fluorspar in the fractures of both systems belongs to one and the same generation.

Intra-ore tectonics. A number of fractures and dislocations, which developed in the ore body during the process of ore formation, conditioned the complex structure of the deposit. The frequent manifestations of these dislocations in different directions precludes a detailed analysis of them according to relative age, permitting only the possibility of distinguishing two groups of intra-ore dislocations: (1) the system northwest 320-- northeast 25 degrees and (2) the system northwest 280 degrees $\angle$ 75 degrees southwest. Numerous veinlets of fluorspar, usually 1 - 2 millimeters, rarely 1 - 1.5 centimeters, in thickness, are embraced by this system. They are all characterized by the unusual, bright, greenish-blue of the fluorspar and by a considerable quantity of crystals and formations of lead glance. The veinlets are located chiefly close to the under side of the vein, occurring in the fluorspar itself, frequently passing over into the fluoritized granites of the under

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side, sometimes (principally in the direction northeast 10 - 20 degrees) even into the pure granites.

Dislocations of the vein in these same directions are rather distinctly expressed. They are characterized by an amplitude not exceeding 10 centimeters; the direction of dislocation is always such that the southeastern part of the vein is moved to the southwest.

The system 280 degrees $\angle$ 75 degrees southwest is characterized by frequent dislocations, which are expressed in the formation of extremely complex, repetitive breccia along the whole upper side of the ore vein. The dislocations which repeatedly followed one another alternated with the introduction and deposit of fluorite, which cemented the breccia-like fluorspar fragments. This material again was subjected to crushing and grinding and again cemented by the addition of fluorite. The number of such phases of crushing, which alternated with ore-deposit, is rather considerable, in any case not less than three.

Inasmuch as the veinlets of the previous system always are sharply broken near the breccia-like zone, the last intra-ore direction (280 degrees) is of younger veinlets of greenish-blue fluorspar and a "podvishka" with a trend northwest 320 degrees -- northeast 25 degrees.

Post-ore tectonics. Among the dislocations, which followed the ore process, two systems are sharply developed.

The first system (280 degrees $\angle$ 75 degrees southwest) is

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expressed by a magnificent mirror of slide, which is detected without any traces of interruption for the whole extent of the ore body, both along the trend and also along the dip. The mirror runs through in the small fluorspar and granitic breccia, ground to a fine-grained, sometimes dust-like state. The surface of the mirror is excellently ground and has a slightly undulating form. Strokes and slots with a dip to the southeast at an angle of $\angle 45$ degrees stand out clearly. The mirror is a surface of fault dislocation with equal ranges of the horizontal and vertical displacements. The nature of the tendency to splinter of the slots indicates the relative displacement of the upper casing of the vein upwards to the northwest; its range is obscure. It is possible to consider that the range in general is not great, not exceeding several tens of meters.

The second group of post-ore dislocations, with a trend northeast 50 - 60 degrees and with a dip to the northwest $\angle 50 - 70$ degrees, is directed at an angle of nearly 60 degrees to the trend of the ore body and is detected in all of the horizons of the latter. In age, these dislocations are the youngest, inasmuch as they distinctly cut and displace the described mirror. Usually, they are represented by irregular fractures, filled with coarse fragmental material from the material of the upper and under sides of this displacement. Fractures, the majority of which are gaping, sometimes contain different products, which alternate in layers, of the disintegration of zinc blende (smithsonite, calamine, hydrozincite and others).

Although the graduated dislocations of this system with the displacement of the southeastern part of the deposit to the

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northeast in relation to the northwestern part have an insignificant amplitude (1 - 5 centimeters), they all noticeably indicate the position of the ore vein in the eastern part of the deposit.

The chief dislocations of the pre-ore and intra-ore dislocations in the deposit, both in their nature and also in relative sequence of appearance, conform to the elements of variscitic tectonics in the Takob region, which, to a known degree, determines their age, and with them the age of the deposit itself. Regarding the post-ore dislocations, there is no conclusive data on their connection with the variscitic or with the Alpine orogenesis.

MORPHOLOGY OF THE ORE BODY

The ore body is a sharply dropping vein with a west-northwest trend. In connection with the absence at short distances of sharp bulges and constrictions, the ore body is characterized as a regular laminated vein.

In view of the fact that the contact of the vein with the wall rocks is expressed insufficiently clearly, its exact orientation is determined by measuring the direction of the longitudinal fracturing, by the trend of the sulfide veinlets, the banding in the fluorspar, and also the stratification of the mirror of slide. The trend of the vein fluctuates from 286 to 308 degrees, rarely exceeding the limits of 288 - 305 degrees.

The dip of the ore body is always to the southwest, on the average 75 - 76 degrees, sometimes with a deviation of 3 degrees, rarely of 5 degrees.

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The ore of the Takob deposit is traced for a distance of nearly 960 meters. The ore body, according to the extent to which it has been investigated and studied, is divided into three sections: the Eastern, the Central and the Western. Prospecting was concentrated almost exclusively in the Central part, as a consequence of which it has been studied sufficiently both from the surface and also to a depth.

The Eastern section has been traced only on the surface by prospecting, but the Western section, up until 1935, existed only hypothetically.

Morphologically, the Central section is a small "grivka", running out from the divide and oriented in a direction of nearly 30 degrees.

The ore vein intersects the "grivka" almost transversely, being traced on the northwest and southeast slopes by a number of rocky outcroppings, in all for a distance of 335 meters.

The Eastern section is a direct continuation in an easterly direction of the central section from the groove of fluorspar.

Morphologically, the section is the northeast slope of the divide, stretching in a northwest direction, highly complicated by a number of deeply-cut, small gullies and "grivki".

In the Eastern section are a number of outcroppings of the ore body, oriented in the direction of the trend of the ore body of the Central section (290 - 300 degrees). In the western part of the section there are separate disconnected outcroppings and eluvia

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of fluorite; in the eastern part, these outcroppings comprise an unbroken, characteristic wall 5 - 8 meters high, along which follows a large mirror of slide, which always accompanies the upper side of the vein in the Central section. The overall extent of the Eastern section comprises 180 meters.

By the Western section is understood the part of the deposit which does not crop out, located to the west of the last working of the Central section (Pit No 1), which goes out under the terrace deposits of the Takob River.

The assumption that there was an ore body here was confirmed in 1935 by bore hole No 1-bis, which is cut through to a depth of 140 meters into the fluorspar vein.

Fluctuations of the thickness of the ore body are rather considerable -- from 5.40 to 0.30 meters, at the most, and usually from 4.60 to 0.80 meters. The increase or decrease of the thickness occurs rather evenly.

It is possible to state a certain increase of the thickness of the ore body with the depth to the horizon of tunnel No 1 (from 2.10 to 3.15 meters) and its constancy as far as the horizon of Pit No 1 (3.20 meters).

The average thickness of the whole deposit must be adjusted to the thickness in tunnel No 1, which comprises 3.15 meters.

STRUCTURE AND MATERIAL COMPOSITION OF THE ORE BODY

The intensive development of dislocations highly complicated

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the structure of the ore body, depending on the appearance of different types of ore.

A number of longitudinal dislocations, alternating with the phases of ore deposit, caused a sharply expressed banding of the ore body.

A. V. Gulyayeva [93] distinguishes three types of ore, which characterize the individual strips or zones of the deposit: (1) fluor-spar-sulfide ore (central part of the ore body), (2) complex ore breccia (upper side) and (3) fluoritized granites (chiefly along the upper casing of the ore body).

Inasmuch as the processes of metasomatism played an essential role in the formation of the ore body, the boundaries between the individual ore zones usually are not sharply expressed (Figure 1).

All the types of ore are most fully represented in the Central section, which is well-studied and opened on various levels.

Fluorspar-Sulfide Ore

Fluorspar-sulfide ore is the main and most essential, properly vein, component part of the ore body, characterizing all of the morphological characteristics of the latter noted above. Its thickness in the Central section usually fluctuates from 2 to 3 meters. The basic mass of the sulfides of lead and zinc is coordinated to this zone.

Ore of this type is green and white, highly shattered and pressed, sometimes partially sheared, and in places weakly brecciated.

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Fluorspar of several generations, corresponding to the second and third generations in the general scheme of mineral formation, is the predominating component part of the ore, in the form of a coarsely crystalline and crystalline-grained, semitransparent aggregate of light-green, bluish-white and sometimes green color, disappearing under the action of sun rays. The mineral is broken up by a thick network of hair-like fractures. In addition, a large fracturing is observed, by which is conditioned the irregular or parallelepiped cleavage of the ore body. Owing to the fine fracturing of the fluorspar, it is almost opaque, with a somewhat dull finish. During heating over a gas burner, it bursts with rather great force, fluorescing with a violet color, independently of the natural color, and is discolored [93].

Around the fluorspar are included: fragments of wall rocks, vein quartz, lead glance, zinc blende, calcite, calamine, smithsonite, cerussite and others.

Fragments of wall rocks, always with corroded edges, play an essential role and considerably influence the quality of the ore. They are represented by fragments of granite of different sizes, more rarely of aplite and hornstone, and also by separate grains of quartz, feldspar, and accumulations of sericite. The distribution of them in the ore is extremely irregular. Sometimes they are scattered in insignificant quantity in the form of small, isolated grains or aggregates of a size from a millimeter to 0.2 - 0.5 millimeter, at other times large fragments of wall rock accumulate in huge quantity in the form of cubes or blocks up to 0.25 - 0.5

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meter in diameter and 1 - 2 meters in length, displacing the vein material. Together with this, there is a section completely free of them, especially in the central part of the ore body.

Figure 1. Scheme of the structure of the Takob ore body. 1 - granite, 2 - ore breccia, 3 - fluorspar-sulfide ore, 4 - fluoritized granite, F - main post-ore dislocation, f - small dislocations.

Quartz (1.5 - 15 percent of the entire ore mass) so clearly coalesces with the fluorspar that it is scarcely perceptible. It is represented chiefly by a cherty variety, which was precipitated after the fluorspar, and forms in the fractures of the fluorspar a network of irregular veinlets from several millimeters to 0.02 - 0.4 millimeter in thickness, sometimes amounting to 0.2 - 0.4 centimeters, highly eroding and displacing the grains of fluorspar, sometimes as far as complete pseudomorphoses. In addition, the quartz forms small grains, 0.15 - 0.03 to 0.02 - 0.003 millimeters in size; sometimes, finely-prismatic quartz is encountered, up to 0.03 millimeter in size (rarely less), which covers the walls of the microscopic cavities in the fluorspar, which is found in clear paragenetical connection with the lead glance.

The greatest quantity of quartz is coordinated to the under side of the fluorspar zone, near its boundary with the fluoritized granite.

Lead glance in the main mass is concentrated usually in the marginal part of the fluorspar zone along the zone of complex

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ore breccia adjacent to it. In the remaining parts it forms only individual veinlets or pocket-like phenocrysts among the fluorspar. The sizes of its formations fluctuate within broad ranges from 0.20 to 0.8 - 0.9 millimeter, sometimes to 0.015 millimeter. The lead glance usually contains, in small quantity, prismatic grains of quartz, from 0.03 to 0.08 millimeter in size, and also small individual grains of fluorspar up to 0.05 millimeter and round grains of zinc blende, 0.5 - 0.035 millimeter in diameter.

As a rule, the formations of lead glance are surrounded by an unbroken cerrusitic border, on the average nearly 0.02 - 0.08 millimeter wide, sometimes entirely replacing it; frequently, a coating of smithsonite is observed, the result of the oxidation of the zinc blende.

An evident decrease of lead is noted along the trend of the ore body to the east, within the limits of the explored (Central) part, where, within the limits of the fluorspar zone, the average content of it does not exceed 1.5 - 2 percent.

Zinc blende most often of all is encountered in connection with the lead glance; it either is included in it or is located along the edge of its grains. More rarely, grains of zinc blende are found in the fluorspar, and frequently in grains of calcite. Usually, they are, as the sulfides of lead also, along the edges and fractures, surrounded by a coating of the products of their oxidation -- smithsonite; frequently they are entirely transformed into smithsonite, hydrozincite and calamine. This circumstance acquires an important significance, inasmuch as the oxidized minerals

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are fluoritized with difficulty.

The average content of zinc in the ore is nearly 1.5 percent.

Calcite forms sporadically diffused lenses or pockets among the fluorspar, having been precipitated earlier than the latter. A large part of the calcite is encountered near the under side of the vein zone proper and is present only in the western part of the deposit in its middle horizons. The grains of calcite usually are displaced by fluorspar, so that from formations with a size from 4 - 5 to 1 millimeter, only sections from 0.09 - 0.05 millimeters remain.

Besides the described component parts of the ore from the fluorspar zone, admixtures, like the thick pelitic particles, which are scattered almost everywhere in the fluorspar, should be noted, and also the scales and flakes of mineral from the kaolin group, which are contained in the ore in negligible quantity.

Qualitatively and quantitatively, the described type of ore is the basic object of industrial utilization on all levels, discovered by prospecting, chiefly in the western half of the explored section, inasmuch as in the eastern half of the latter the ore of this type, as a consequence of the contraction of the ore belt, plays an insignificant role.

The chemical analysis of the fluorspar ore from the central part of the vein (in percent) is as follows (by the analysts of the IMS -- Sokolova, Voronkova, Ponemunskaia and Chubarova): CaF_2 --

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78.62; SiO₂ -- 9.36; Pb -- 5.82; CaO -- 0.42; S -- 0.68; Zn -- 1.00;
 CO₂ -- 0.59; Al₂O₃ -- 0.06; Fe₂O₃ -- 0.78; PbO -- 1.91; PbS -- 4.68;
 H₂O -- 0.21.

Complex Ore Breccia

Complex ore breccia usually composes the upper side of the vein in the form of a relatively sustained strip, 0.3 - 0.6 meter in width, which is the product of repeated crushing and subsequent cementation of the quartzitic-fluorspar material, as a result of displacement which developed in the upper side of the vein even before the conclusion of the process of ore-deposit (see above). Among the complex ore breccia, several varieties stand out.

Most frequently encountered is a variety in the form of a compact rock with a distinct, brecciated structure; in it are seen round, more rarely angular, fragments of light-green and pale-violet fluorspar up to 4 - 5 centimeters in diameter, kaolinized relics of wall rocks, sometimes grains of lead glance, which are located among the dense cemented mass. The cement is light-gray, fine-grained, usually very compact.

Under the microscope, the rock has the form of complex breccia, in which fragmental material is represented by the predominating fluorspar, by individual grains and concretions of the minerals of granite, frequently, also, by pyritized hornstone and aplite, if the latter is present in the walls of the vein. The fluorspar among the fragments with a size of 0.2 millimeters is distinguished by its relative purity, by sharply expressed fractures of cleavage. The form of the fragments is angular, more rarely round, with corroded edges. The relics of granite and aplite consist of

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either individual grains or concretions of undulatingly dying-out quartz and changed feldspar, usually with uneven, corroded edges, or else of spherical concretions. Fragments of pyritized hornstone, usually round, negligibly corroded, are present in relatively small quantity or are absent altogether. Their size fluctuates from fragments invisible to the naked eye up to 0.2 - 0.5 millimeters.

In the fragments of granite and hornstone are observed veinlets of fluorspar and sometimes quartz, not going beyond the limits of these fragments, which indicates the nature of the cement of the original breccia.

An allotriomorphic-grained aggregate of fluorspar and quartz serves as the cement of the breccia, or with a chert-like structure or else, in case of the predominance of the fluorspar, the quartz has idiomorphic forms with a size from 0.08 - 0.02 millimeter. Apparently, the crystallization of the fluorspar and quartz took place in the main part simultaneously with the somewhat earlier formation of the small part of the quartz. The quantitative interrelationships of these components fluctuate within rather broad limits: in some cases quartz predominates, in others fluorspar. The proportion of cement and fragmental material is represented as 1 : 1 or 2 : 3.

The described variety of breccia usually contains a certain amount of lead glance, which pertains to two generations: lead glance as a fragmental material, and lead glance in the cement, in the form of irregular, branched, pocket-like concretions, which were precipitated later than the basic components of the cement (Figure 2).

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The presence of a small quantity of products of the oxidation of the sulfides of calamine, cerrusite and smithsonite is characteristic also; the first forms veinlets, more rarely pocket-like concretions, and the latter two form borders around the sulfides, more rarely forming veinlets.

The other variety of breccia is characterized by the presence in the fragmental material of angular fragments of the breccia described above (Figure 3). A grayish-white compact mass, consisting of a matted, fine-grained, siliceous aggregate of the cherty type is the cementing substance.

After the secondary brecciation and cementation, the rock again is dissected by infrequent, thin veinlets of fluorspar of the fourth generation, which here and there also forms cockade accretions around the fragments of complex breccia (Figure 4).

Finally, after the formation of the fluorspar of the fourth generation in the zone of the breccia, a tectonic movement again took place, as a result of which the last post-ore breccia of attrition was formed. It is represented either by a finely-fragmental, weakly pressed mass of light-gray color, or else by a mealy, quick material. Under the microscope, small, 0.35 - 0.6 millimeter, fragments of fluorspar are seen, connected by an opaque or semitransparent pelitic mass, sometimes with such supergene formations as secondary calcite and the products of the oxidation of zinc and lead.

Figure 2. General view of the ore breccia (microphoto).

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As a consequence of the small role of the breccia zone in the structure of the ore body, separate analyses of this type of ore were not carried out. According to the data of trench sampling, the total content of CaF_2 comprises nearly 60 - 62 percent, remaining rather sustained both along the trend and also along the dip. Transversely to the trend of the zone, the content of CaF_2 quickly decreases, increasing in the upper side toward the fluorspar zone proper and sharply decreasing in the under side because of the fragments of wall rocks.

Fluoritized Granite

Under this designation, the wall rocks in the casings of the ore body, with a content of CaF_2 of approximately 40 and not lower than 25 percent, representing the brecciated granites or aplites with fluorspar cement, are conditionally separated.

Ore of this type in its main mass is associated with the under side of the ore vein in the form of a zone up to 3.0 meters wide, directly bordering the fluorspar-sulfide zone proper, and acquires especially important significance in the Eastern section and the eastern half of the explored part of the ore body.

On the upper side of the casing of the vein, fluoritized wall rock also is observed; however, according to the size of the outcrop of the zone of complex ore breccia, the content of CaF_2 sharply drops and in the majority of cases does not exceed 10 - 15 percent. Regarding the under side, here the content of CaF_2 also changes sharply at the boundary of the fluorspar ore proper; nonetheless, it always ranges around 25 - 30 percent. In the accompanying

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diagram the approximate curve of the content of CaF_2 transversely to the trend of the ore body, in conformity with the evolved variety of ore (Figure 5) is represented.

Figure 3. Breccia in the breccia -- complex ore breccia (microphoto).

The mineralogical composition here is the same as in the described types of ore; only calcite is absent. The main mass of this ore consists of quartz, feldspar and sericite; the minimum size of it reaches 0.2 - 0.5 millimeter, more rarely 0.09 millimeter. The sulfides of lead and zinc form an infrequent, diffused impregnation; if in the proportion of lead it sharply decreases in comparison with the vein part of the ore body, then the content of zinc here almost does not drop. This circumstance is easily explained by the migration of the oxidized products of this metal from the ore vein to the wall rock.

In the fluoritized granite, green fluorspar forms thin, branching veinlets, the quantity and thickness of which gradually diminishes in proportion as the granite becomes less crushed at a distance from the vein.

Figure 4. Cockade with fluorspar of the fourth generation (close to natural size).

CHANGES OF THE WALL ROCKS

The leucocratic granites which enclose the Takob fluorspar

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vein are subjected, in connection with the processes of ore formation, to an intensive secondary change; it is manifested first of all in occurrences of "kataklaaz", adjoining the vein of granite. Chemical-mineralogical changes of the wall rocks are characterized by intensive metasomatal replacement of some minerals by others, with almost complete loss of an entire series of elements and the introduction of other component parts.

At first, the disintegration of the feldspars and dark-colored minerals takes place, with the formation of sericite, argillo-kaolinic particles, chlorite, epidote, and sometimes carbonate. These processes are accompanied by the loss of such elements as Ca, Mg, Na. Further, in the fractures of the crushing of granite, quartz and fluorite are deposited, replacing the rock, sometimes leaving relics of it and conditioning its gradual transition to the vein body.

"Kataklaaz"-ation and metasomatosiis, as a rule, considerably more broadly reveal the presence of wall rock on the under side of the vein. "Kataklaazy" are especially widespread, appearing for a distance of 65 meters from the vein in the undulating dying-out of quartz. Nearer to the vein, the dying-out of grains of quartz acquire an aggregate nature, and curvature and displacements of the duplicate seams of plagioclase appear. In proportion to the proximity to the vein in the granite they begin to appear and the thin, matted veins thicken, giving to it, at a distance of 3 - 4 meters from the contact with the vein, a breccia-like appearance, but at a distance of 2 - 2.5 meters, the form of typical breccia.

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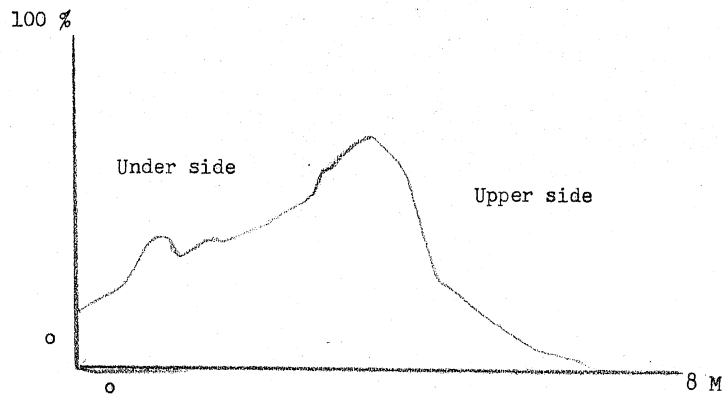
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Figure 5. Approximate diagram of the content of CaF_2 in the different types of ore of the Takob deposit (transversely to the trend). 1 - granite, 2 - fluoritized granite, 3 - fluorspar-sulfide ore, 4 - ore breccia.

The chemico-mineralogical changes lead to the process of sericitization, kaolinization, carbonatization, chloritization, silicification, pyritization and fluoritization.

Sericitization and kaolinization. The process of change begins with the sericitization and turbidity of the feldspars, which encompass a zone over 100 meters wide; in addition, besides the influence of the ore solutions, autometasomatism also played a certain role earlier.

Near the casings of the vein the grains of plagioclase frequently are entirely replaced by an aggregate of sericitized scales; the potash feldspars pass over into a white kaolinized mass.

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Carbonatization of the plagioclases is not characteristic. Simultaneously with the change of the feldspars is observed the chloritization of the dark-colored components, with the simultaneous formation of irregular concretions of a hydrated ore mineral. In proportion to proximity to the vein, these occurrences are changed by the breaking up of the dark-colored component parts into minerals of the epidote and chalcedony group, more rarely of quartz.

Albitization of the plagioclases is observed in connection with the chertization of the rock in direct proximity to the vein or in the relics of wall rock within the ore body.

Pyritization accompanied both the upper and also the lower side of the vein at a distance 2 - 3 meters from the casings. Pyrite, usually limonitized, forms well-defined cubes, more rarely irregular grains from 2 - 3 to 0.01 millimeter on the edge.

The processes of chertization of the wall rocks is widely developed in the Takob deposit. During observation under the microscope, the impression is created that the greatest quantity of silica was deposited, not in the immediate neighborhood of the vein body, but approximately 0.5 - 1.0 meter from it, especially in the under side, where sections of unbroken hornstone appear, with highly corroded relics of granite floating in it.

The hornstone is a compact, light-gray or gray, fine-grained rock, with infrequent remains of granitic material; a typical relic structure is possessed by it, and it consists of very small, close concretions of irregular grains of quartz. The relics of granite are represented by corroded grains of quartz, of more

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secure albite, scales of sericite, now and then by chlorite and aggregates of epidotic minerals. The chertization of the granitic breccia is concluded by the formation on the walls of the remaining cavities of a small quantity of fine-prismatic crystals of quartz.

More often, the hornstone forms a fine network of veinlets in the fractures of shattering in the granite, which, in proportion to proximity to the vein, are transformed into an unbroken mass, which replaces the primary component parts of the rock.

Fluoritization. The process of fluoritization of the wall rocks occurs after the chertization and has approximately the same nature. Primarily, in the fractures of the "kataklaz", the fluorspar forms a branched network of veinlets and "korochki", the number of which increases in the direction of the vein. The veinlets widen; bulges and knots appear as a result of the replacement of the rock-forming minerals of granite by fluorite. Directly at the casings of the ore veins, the fluoritized granite is breccia from the corroded fragments of wall rocks, buried in the fluorspar cement. Macroscopically, the rock appears to be entirely saturated with green fluorite, which closely interlocks with the granitic material.

As a consequence of this, the transition from the vein body into wall rock is accomplished extremely gradually. As a rule, in the under side the fluorite penetrates considerably more intensively and farther than in the upper side.

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GENESIS OF THE DEPOSIT

The Takob deposit, with respect to age, is connected with the variscite magmatic activity, inasmuch as nowhere in the Zeravshano-Gissar system neither magmatic rocks nor any mineralization of younger age is known.

The Takob fluorspar-lead deposit is coordinated to the marginal part of the variscite granitic batholite, richest in quartzitic and pegmatitic veins. It is essential that with the formation of the latter is connected the introduction of CaF_2 and PbS , which serves as a definite indication of the migration of the fluorine in connection with the variscite magmatic activity. The further concentration of these elements in the hydrothermal phase also led, apparently, to the formation of the Takob fluorspar deposit.

Indirect indications on the possible existence of a still uncooled magmatic furnace in the region, which provides the origin for the hot, thermal springs which were coordinated to the Alpine fracture (see the tectonics of the region), does not seem to us an adequate reason for connecting the Takob deposit with Alpine magma. This all the more so does not necessitate that the pre-ore and intra-ore tectonics of the deposit are tied up closely with the system of variscite tectonics in the region.

The formation of a fault fracture, which is the basic channel for ore deposit, is connected with the phase of expansion, which set in after conclusion of fold formation and the formation of the variscite intrusive bodies; in addition, a number of cir-

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circumstances permits the assumption that the basic direction of the fracture was set still at the moment of cooling of the granitic massif at that time when the pegmatitic veins also began to form. Later, in connection with the expansion of the region which set in, a widening of this fracture occurred, with the formation of a cavity filled by the granitic and cherty breccia.

Later, this section for the whole extent of the variscite, and possibly, even, of the Alpine orogenesis, was structurally a weakened spot, in which the tectonic forces which had acted repeatedly found their discharge. The rejuvenation of the fracture alternated with phases of ore deposit, which at the deposit number not less than four, not considering the supergene phase. The fluor spar of each of these generations bears in itself clear traces of the ensuing crushings and the inflow connected with them of new portions of ore material.

The association of minerals, the duration of ore deposit in time and the character of the changes of the wall rocks, which are distinguished by the complete absence of signs of pneumatolysis, clearly indicate the hydrothermal nature of the deposit and its formation at average depths.

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Stages of Mineral formation	Hypogene				Supergene	
	I	II	III	IV	V	
Minerals						
Quartz						
Fluorspar						
Lead glance						
Zinc blende						
Calcite						
Pyrite						
Cerussite						
Smithsonite						
Calamine						
Hydrozincite						
Wulfenite						
Tectonics elements	T _i	T _{ii}	T _{iii}	T _{iv}	T _v	T _{vi} T _{vii}

Figure 6. Scheme of the formation of the Takob deposit of fluorspar.
 T_i - shaping of the direction of the fracture in connection with the cooling of the granite; T_{ii} - widening of the fracture with the formation of a cavity, filled with loose granitic and cherty breccia; T_{iii} - crushing of the vein, chiefly in the upper side; T_{iv} - crushing of the upper side of the vein; T_v - dislocation in the direction 320 degrees; T_{vi} - post-ore fault in the upper side; T_{vii} - dislocation in the direction 50 - 60 degrees.

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An analysis of the materials of the expedition of IMS [93] and the party of the Central Asian Geological Trust [88] permits us to divide the whole process of formation of the deposit into several stages and to distinguish among the latter the most essential phases of mineral formation effecting the practical significance of the deposit. However, it should be noted that the scheme which we propose is not free of defects, inasmuch as the repeated inflow of the hydrothermal springs, very close in composition, highly hamper the restoration of the course of the process of mineral formation (Figure 6).

The process of ore-deposit is divided into four basic stages of mineral formation, with a more or less different composition of the hypogene solutions, which are supplemented by a fifth stage, formed by supergene (descending) solutions. Each stage of mineral formation was caused by the resumption of tectonic movements in the region of the deposit.

I. The cracking of the granite, in connection with its cooling, preceded the beginning of the process of mineral formation. During this period, the crystallization of hornstone and the infiltration of a negligible quantity of fluorite into the walls of the fracture took place, with a broad development of the processes of replacement of the primary minerals of the granite.

II. At the moment of the second stage of mineral formation, which followed the enlargement of the fracture, the role of silicic acid in the hydrothermal springs was almost negligible; fluorine and sulfide compounds predominated. The main mass of fluorspar,

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usually coarse-grained, of white and green shadings, was crystallized in the open fracture. The beginning of this stage is characterized by the appearance in the solutions of a certain quantity of carbon dioxide, which conditioned the appearance in the vein of calcite. Judging by the numerous pseudomorphoses of secondary minerals in calcite, as noted by A. L. Ponomarev [93], calcite originally played, undoubtedly, a more significant role in the deposit. The stage was concluded by the deposit of sulfides of lead and zinc; the latter was preserved in very small part, having been replaced by oxidized compounds.

III. The third stage is characterized by the enrichment of the vein by fluorspar, chiefly along its upper side, which set in owing to the strong crushing of the vein still prior to the conclusion of the process of ore deposit. The fluorspar of the third generation plays, together with the fluorite of the second generation, an essential role in the deposit, cementing the ore breccia of the upper side of the vein, infiltrating also into the central part of the latter. The role of the sulfides here sharply decreases.

IV. Following this, the upper side of the vein again is exposed to a breaking down, as a consequence of which the so-called complex ore breccia develops with a quartzitic cement, where fluorspar of the first three generations is present among the fragmental material. After diagonal dislocations with a trend of 320 degrees, which developed among the whole vein mass, including also the complex ore breccia, the formation of fluorspar of the fourth generation takes place, by which, also, the ore process is completed. This fluorspar fills the fractures of the indicated direction, is crystallized in the cavities and frequently forms characteristic concentric accumulations on the periphery of the fragments of the complex breccia.

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V. After the conclusion of the ore deposit in the deposit, post-ore dislocations developed, which are localized, like the intra-ore dislocations also, in the upper side of the vein. Then the supergenic solutions exert their influence, oxidizing and re-depositing the sulfides of lead and zinc. As a consequence of the climatical peculiarities of the region, the low level of the ground waters and strong fracturing of the rocks, the processes of oxidation at the deposit play an essential role. All of the mining operations, which opened the deposit to a depth of 145 meters, still have not passed beyond the limits of the oxidized zone.

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INVESTIGATION OF THE DEPOSIT

As has already been shown, the Takob deposit has not been investigated for its entire extent to the same degree. Up to 1935, all prospecting operations were concentrated only in the Central section, for a distance of 335 meters, where the ore body was traced from the surface by trenches and clearings at a distance of 15-20 meters from each other. By means of underground operations in the years 1933-1935, the deposit was opened on three horizons: horizon I - tunnels No 3 and 4 (begun in 1934 and continued in 1935), which are located 60 meters, vertically, from the highest point of the relief of the Central section; horizon II - tunnel No 1 (1933-1935), 40 meters below horizon I, and horizon III - drift pit No 1 (1934), 45 meters below horizon II. Thus, the overall depth to which the deposit is opened by prospecting operations in the Central section comprises 145 meters, vertically, from the highest point of the relief.

In 1935, drilling operations were carried out in this same section for the purpose of cutting the ore body to a depth on the average "... as far as a depth of 273.3 meters." The eastern section is opened only by shallow trenches, and in 1936, underground geological-prospecting operations were carried out in it.

The results of numerous analyses of samples in the Central section characterize the deposit, with sufficient completeness, from the point of view of its material composition (Tables 1, 2, 3 and 4).

Fluorspar. A basic mineral composing the ore body is fluorspar, which is represented by a coarsely crystalline variety,

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milk-white or of a greenish color. Its distribution in the ore, as generally in the deposit, is rather constant.

The north-western part of the section is distinguished by the highest content of CaF_2 , in which section it reaches 86 percent in the ore body proper. At the extreme south-eastern end of the central section, the content sharply decreases as a consequence of the narrowing of the ore body, and reaches only 20 percent.

The thickness of the ore body also is subject to fluctuations. In the south-western part, with an average content of CaF_2 above 79 percent, it reaches up to 3.00 meters. As the vein is traced to the north-east, its thickness, with that same saturation, tapers out almost completely.

Most significant is the change of the content of CaF_2 transversely to the trend of the ore body, which, in proportion to the transition from the fluorspar zone proper to the fluoritized granites, is maintained in the whole extent of the ore body.

In the upper side, where these changes of content are most clearly expressed, with the transition to the wall rocks (fluoritized granites) the content of CaF_2 in the ore sharply drops from 38-40 percent to 2-3 percent in a vein 0.1-0.2 meter thick.

The most even transition from the ore body proper to the fluoritized granites characterizes the under side, where the content drops evenly, approximately 5-10 percent for each meter of thickness.

In individual horizons, these changes are less significant; however, they are unequally significant. In the extent of the central

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Table 1

Tunnel No 1, crosscut 9, Trench No 33 at a distance of 106.20 meters
from the mouth

	No of sample	From be- ginning of trench, meters	Length of section of trench, meters	Content in percent				Rock
				CaF ₂	Pb	Zn	SiO ₂	
Upperside	389	0.00						Fluoritized granites
		0.50	0.50	---	---	---	---	
	390		0.50	1.72	---	---	---	
	391	1.00	0.50	1.30	0.07	---	---	
	392	1.50	0.50	3.70	0.50	0.11	68.24	
Ore body proper	393	2.00	0.50	61.06	3.70	0.64	29.40	Vein zone
	394	2.50	0.50	78.73	4.01	1.41	10.36	
	395	3.00	0.50	72.06	1.01	1.89	16.91	
	396	3.50	0.50	70.55	1.60	0.91	20.30	
	397	4.00	0.50	50.64	3.07	0.58	32.73	
	398	4.50	0.50	45.41	2.74	0.54	35.86	
Underside	399	5.00	0.50	37.66	6.03	0.46	37.95	Fluoritized granites
	400	5.60	0.50	41.38	3.34	0.46	38.10	
	401	6.00	0.50	32.34	1.21	0.68	45.61	
	402	6.50	0.50	43.93	2.22	1.03	---	
	403	7.00	0.50	34.68	0.44	0.72	---	
		7.50						

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Table 2

Tunnel No 4, Trench No 1

	No of Sample	From beginning of trench, Meters	Length of section of trench, Meters	Content in percent				Rock
				CaF ₂	Pb	Zn	SiO ₂	
Under side	001	0.00	0.55	5.36	1.22	0.27	67.47	Fluoritized Granite
Ore body proper	002	0.55	0.20	38.60	2.04	1.04	50.49	Veinzone
	003	0.75	0.50	78.87	1.91	1.87	12.19	
	004	1.25	0.50	88.93	0.13	0.66	6.34	
	005	1.75	0.60	83.99	0.53	0.99	10.74	
	006	2.35	0.50	59.86	1.54	0.74	39.47	
Underside	007	2.85	0.50	44.53	1.30	2.19	38.27	Fluoritized Granite
	008	3.35	0.50	30.01	0.57	0.39	52.29	
	009	3.85	0.60	34.86	0.16	0.36	45.76	
	010	4.35	0.50	33.10	0.23	0.33	49.29	
	011	4.85	0.50	15.87	0.04	---	---	
	012	5.35	0.50	17.09	---	---	---	
	013	5.85	0.50	48.80	---	---	---	
	014	6.35	0.50	12.97	---	---	---	
		6.85						

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Table 3

Pit No 1, crosscut No 1, Trench No 2

No of Sample	From beginning of trench, Meters	Length of section of trench, Meters	Content in percent				Rock
			CaF ₂	Pb	Zn	SiO ₂	
Ore body proper		0.00					
	3	1.00	90.01	3.51	0.53	2.65	
		1.00	76.19	1.94	1.96	13.93	
	4	0.60	42.45	0.87	1.33	35.49	
Underside	5	2.50					
		0.50	16.08	0.16	0.76	58.14	
	6	3.00					
		1.00	17.19	0.34	---	---	
	7	4.00					
		1.00	30.43	0.32	---	---	
	8	5.00					
		1.00	24.38	0.14	---	---	
	9	6.00					
		0.60	17.04	0.29	---	---	
	10	6.60					
Fluoritized Granite							

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Table 4

Pit No 1, crosscut No 1, Trench No 34. At a distance of 9.50 meters
from the mouth

	No of Sample	From be- ginning of trench, Meters	Length of section of trench, Meters	Content in Percent				Rock
				CaF ₂	Pb	Zn	SiO ₂	
Upside	405	0.00						
	406	0.30	0.30	10.43	1.51	0.00	61.03	Fluoritized Granite
			0.40	38.80	6.39	0.45	34.72	
Ore body proper	407	0.70	0.50	79.51	2.73	1.76	5.88	Vein Zone
	408	1.20	0.50	79.77	1.69	0.84	7.54	
	409	1.70	0.50	88.82	2.34	2.13	4.93	
	410	2.20	0.50	64.54	1.33	2.14	20.38	
	411	2.70	0.50	64.11	0.80	1.71	24.35	
	412	3.20	0.50	35.05	0.16	2.49	48.02	
Underside	413	3.70	0.50	31.48	0.36	0.00	48.18	Fluoritized Granite
	414	4.20	0.50	37.50	2.64	0.80	---	
	415	4.70	0.50	14.44	1.48	0.39	---	
	416	5.20	0.50	8.86	---	---	---	
	417	5.70	0.40	6.93	---	---	---	
		6.10						

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section, along the surface, as has been shown above, the content of CaF_2 varies from 78 percent (bench No 1) to 20 percent (in bench No 7), which is connected with the spacing of the workings on different hypsometric horizons, and also with the dip of the ore vein.

The first horizon is characterized by the maintaining of the content, which here fluctuates, in the ore body proper, from 89.20 to 62.70 percent and is explained by the presence in the composition of the ore body of sections of non-displaced granite, which depletes it in individual points.

But this circumstance is verified also by the workings of the second horizon, where for the entire extent of tunnel No 1 the content fluctuates in the ore body proper from 88.93 to 61.20 percent.

The third horizon affords a certain increase of the impregnation by the fluorspar, which here reaches 86.82 percent.

All of these data together indicate a certain increase of the impregnation by the fluorspar with depth, because of the decrease in the content of silicon dioxide in the ore.

Lead. Minerals which contain lead are distributed extremely unevenly in the ore body and for the most part are concentrated in the narrow sulfide zone, 0.5 meter from the upper side, and in the form of insignificant accumulations and phenocrysts in the remaining part of the fluorspar.

As the results of the analyses of samples show, the content of lead fluctuates from 1 to 8 percent, and in individual cases up

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to 16 percent, with an average content in the deposit of 2.52 percent.

Zinc is distributed in the deposit similarly to the lead; however, its content varies from traces to 5-6 percent. A certain increase of the content of zinc is observed in the surface oxidized zone, chiefly because of the carbonates of zinc.

The average impregnation of the deposit by zinc comprises 1.52 percent. However, as a consequence of the absence as yet of methods for the extraction of the zinc during flotation, the question of the extraction of the latter remains unsolved.

Silver is coordinated chiefly to the sulfides of lead and has practical importance, the more so since its extraction presents no difficulty.

Gold. The impossibility of obtaining it in more significant quantities in the lead concentrate does not permit confirmation of its coordination to the sulfides of lead and zinc.

The extraction of such insignificant quantities of gold is of little interest, inasmuch as it is not worth the expense of extracting it.

RESERVES OF THE TAKOB DEPOSIT

As a result of the operations in 1934-1935, a calculation of the reserves in the Central part of the deposit (Figure 7) was carried out; detailed materials by assaying permitted the analyzing of the ore reserves not only according to categories, but also

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according to the degree of impregnation of the ore by fluorspar, in close connection with its technological properties.

One of the most important moments in the raising of the question concerning Takob, as an industrial object, is the possibility of utilizing the fluoritized granites, which contain a large amount of fluorspar.

In order to be able to compare the different conditions for the utilization of the deposit, a calculation of the reserves was carried out according to three different variations.

The first variation takes into consideration, in the capacity of an ore, only the so-called "purely fluorspar zone" with a content of CaF_2 above 70 percent, where part of the complex ore breccia enters in.

Inasmuch as the Takob ore, as a consequence of the complexity of the mineralogical composition, cannot be utilized to any degree without concentration, and a composite, heterogeneous ore with a definite average content of components must be treated at the concentration plant, it seemed expeditious to conduct the calculation of the reserves in relation to the technological properties of the ore and the average content, on which an enterprise may be planned.

An experiment for the study of the technological properties of ore, similar to those of Takob, in the concentration laboratory of the Institute of Mineral Raw Material, and a comparison of them with American data, permitted the assumption, conditionally, for the purposes of concentration, of the following two varieties according to the average content of fluorspar in the compound ore: the first

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EASTERN SECTION

CENTRAL SECTION

SE

[$\backslash\backslash\phi$ = Pit; $\backslash\backslash\tau$ = Tunnel; Y = Bench; K = Trench; C K B. = Bore]

Scale

20 0 20 40 60 80M

Figure 7. Cross section in the plane of the ore body for the calculation of the reserves.

1 - reserves of category A₂; 2 - reserves of category B; 3 - reserves of category C₁; 4 - reserves of category C₂; 5 - detritus

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variety - with an average content of nearly 70 percent at the time of incorporation into the exploitation of the ore, with a content of CaF_2 not lower than 50 percent, and the second variety - with an average content of nearly 50-55 percent at the time of incorporation into the composition of the mixture of ore, with a lower limit of the content of CaF_2 of 25 percent, whereupon the plant depends on one of these varieties.

As a consequence of such a classification, the reserves of ore are determined according to three variations, of which each subsequent reserve includes the preceding: the first variation takes into consideration in the capacity of an ore only the so-called "purely fluorspar zone" with a content of CaF_2 not lower than 70 percent; the second variation (ore of the first variety is the mixed ore with an average content of CaF_2 in suspension of nearly 70 percent and a lower limit of impregnation of 50 percent; the third variation provides for the utilization of the ore and fluoritized granites with a content of CaF_2 of not lower than 25 percent, with an average content of CaF_2 in the mixed ore.

The results of the calculation of the reserves, verified by the Central Committee on Reserves, are shown in Tables 5, 6, and 7.

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Table 5

Reserves of fluorspar, lead and zinc in the central
section of the Takob deposit, according to variation I

Categories of Reserves	Average Thickness Meters	Average Content in percent			Tonnage			
		CaF ₂	Pb	Zn	Ores	Fluor- spar	Lead	Zinc
A ₂	1.54	75.93	3.73	1.66	31,200	23,000	1,110	520
B	1.20	79.45	1.46	1.45	33,000	26,000	400	480
In all A ₂ +B	1.21	77.79	2.52	1.50	64,200	49,000	1,510	1,000
C ₁	1.21	77.79	2.52	1.50	114,980	89,000	2,900	1,720
Total A ₂ +B +C ₁	1.21	77.79	2.52	1.50	179,180	138,000	4,410	2,720

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Table 6

Reserves of fluorspar, lead and zinc in the central section of the Takob deposit, according to variation II

Categories of Reserves	Average Thickness Meters	Average Content in percent					Tonnage	
		CaF ₂	Pb	Zn	Ores	Fluorspar		Lead
A ₂	2.06	71.46	3.84	1.42	42000	30000	1650	600
B	1.68	70.00	1.29	1.40	54000	37900	700	760
In all								
A ₂ + B	1.83	70.39	2.36	1.41	96000	67900	2350	1360
C ₁	1.83	70.39	2.36	1.41	173000	122000	4080	2450
Total A ₂								
+B + C ₁	1.83	70.39	2.36	1.41	269000	189900	6430	3810

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Table 7

Reserves of fluorspar, lead and zinc in the central section of the Takob deposit, according to variation III

Categories	Average	Average Content						
		in percent			Tonnage			
		CaF ₂	Pb	Zn	Ores	Fluorspar	Lead	Zinc
A ₂	3.72	57.69	2.64	1.35	75800	44000	2060	1070
B	3.07	55.84	1.11	1.07	98700	55000	1100	1060
In all								
A ₂ + B	3.31	56.62	1.77	1.21	174500	99000	3160	2130
C ₁	3.31	56.62	1.77	1.21	314000	178000	5560	3800
Total A ₂								
+ B + C ₁	3.31	56.62	1.77	1.21	488500	277000	8720	5930

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From a comparison of the data of the three variations, it is completely evident that the possibility of utilizing the ore with a low content of CaF_2 acquires great importance for the prospects of the deposit.

In addition, utilizing the thickness of the ore zone considerably is increased, reaching up to 4 and even 6 meters in individual places.

The reserve of ore in this case considerably increases during the comparatively small working out of it. A comparison of the results in the second and first variations shows that the reserve of ore in the utilization of the second variation increases in all the categories almost to 50 percent at the time of the decrease of the average content of CaF_2 in the ore to only 7.4 percent.

A still more impressive increase of the reserves is in the utilization of the poor ores, that is, in the third variation. In this case, the reserves increase up to very great limits, whereupon the concentration plant receives a mixed ore with an average content of CaF_2 of 56-57 percent.

It appears that at the same time the reserves vary according to the variations as 1:1.5:2.7, the average content of CaF_2 in the ore varies accordingly as 1.00: 0.90: 0.73, whereas the content of the metals in the ore vary very insignificantly.

Thus, the third variation affords the possibility of utilizing more completely the raw material base of Takob, the more so since the question regarding the concentration of the ore is positively solved.

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Table 8

Reserves of fluorspar, lead and zinc in the central
section in variety I (variation II, 1935)

Categories of Reserves	Average Thickness Meters	Average Content						
		in percent			Tonnage			
		CaF ₂	Pb *	Zn	Ores	Fluorspar	Lead	Zinc
A ₂	1.87	70.40	2.18	1.50	93300	65700	2360	1410
B	1.41	74.80	2.26	1.33	75000	56300	1700	1010
In all A ₂ +B	1.64	72.37	2.20	1.44	168300	122000	4060	2420
C ₁	1.29	72.90	2.82	1.01	83000	60600	2420	842
Total								
A ₂ +B+C ₁	1.20	72.56	2.58	1.30	251300	182600	6480	1262

Table 9

Reserves of fluorspar, lead and zinc in the central sec-
tion in variety II (variation III, 1935)

Categories of	Average Thickness	Average Content						
		in percent			Tonnage			
		CaF ₂	Pb	Zn	Ore	Fluorspar	Lead	Zinc
A ₂	3.53	55.48	1.76	1.32	175000	97000	3080	2130
B	3.22	50.32	1.42	0.98	175000	88000	2480	1740
In all A ₂ +B	3.41	52.90	1.52	1.10	350000	185000	5560	3870
C ₁	2.41	46.50	1.66	0.87	268000	124000	4460	2330
Total A ₂ +B+C ₁	2.88	50.00	1.59	1.00	618000	309000	10020	6200
In Eastern Section IG ₂	1.17	53.59	---	---	351000	188000	---	---

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Drilling operations, carried out in 1935 by the Central Asian Geological Trust, confirmed the fact that the deposit is sustained to a depth and increased the explored reserves of the deposit. The latter, at the present time, according to the calculation of S. Z. Shifrin, carried out on the basis of materials of the party of the Central Asian Geological Trust, verified by TsKZ, are shown in Tables 8 and 9.

INDUSTRIAL-ECONOMICAL EVALUATION OF THE DEPOSIT

The reserves brought out above, embracing only the Central section of Takob puts the deposit in one of the first places among the known fluorspar deposits of Central Asia. However, these reserves do not exhaust the possibility of a deposit even in this part. Most recently, the question of flotation of the poor ores of Takob, with a low range of content up to 5 percent, has been solved technologically (but not economically). Thus, if it appeared profitable (which must be shown by economic calculations) to mine the ore with a content of CaF_2 lower than 25 percent, then it would possibly expand the raw material base of the deposit in the limits of the explored section.

At the present time, the planning of an enterprise at Takob has as its purpose the guarantee of an annual output of 30,000 tons of concentrate per year, for the production of which nearly 65,000-70,000 tons of ore are required; consequently, an enterprise is guaranteed reserves for a minimum of 10-12 years. During the production of 30,000 tons of fluorspar concentrate per year by the concentrate plant, as a supplementary product will be obtained nearly 1,200-1,400 tons of lead, with a considerable content of silver. Thus, the net cost of the

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Takob fluorspar will be considerably lower than the planned plant at Aurakhmat.

General economic conditions at Takob are completely favorable for the development here of an enterprise.

The presence of water, necessary for the concentration plant, convenient conditions of the relief for the location of an enterprise, and the proximity of the construction of the Varzob hydroelectric station, which is being completed, simplify extremely the organization of an enterprise.

The only negative factor is the relative remoteness from the centers of demand, which is much less a negative factor here than at the deposits of Trans-Baikalia and little different than Aurakhmat.

Conclusion

In conclusion, it is necessary to note that the prospects of the Takob deposit are not limited to the explored Central section.

The Eastern section is of great interest, where single outcroppings of the ore zone to the surface are traced for a more considerable distance than in the Central section.

If the considerable hysometric excess of the Eastern section over the Central which reaches 150 meters, is taken into consideration, and its considerable extent along the trend, it can be assumed that the prospecting of this section can increase, to a large degree, the raw material resources of Takob, bringing them up to 1.5 million tons of ore.

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A certain increase of the reserves can be secured also from the reserves concealed under the detritus of the western part of the deposit.

KULI-KOLON DEPOSIT OF OPTICAL FLUORITE

S. Z. Shifrin

Optical fluorite is a colorless, completely transparent variety of ordinary fluorspar (CaF_2) in the form of crystals or cubes, regardless of their sizes (but not less than 3-5 millimeters on the edge), and is used for the manufacture of a number of parts in delicate optical instruments.

The most important property of optical fluorite is its capacity to freely filter infra-red and ultra-violet rays; the absence of the occurrence of birefringence and the low index of refraction make it an irreplaceable material for optics, which act in the outer parts of the spectrum.

Owing to these properties, optical fluorspar at the present time is being introduced all the more widely into technical optics for the rectification of chromatic aberration, for the manufacture of apochromatic lenses for microscopes, prisms for spectrographic and plate instruments, which radiate short-wave rays.

Its irreproachable transparency and colorlessness is a basic requirement which is presented to optical fluorite. With respect to the latter, certain variations are permitted; weakly colored varieties can be employed in the less delicate instruments.

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The rareness of optical fluorite in nature and the extremely insignificant quantities of it in the individual deposits make it deficient in the world market; reliable firms are forced to manufacture large parts from small fragments cemented together.

The world deposits of optical fluorite are extremely negligible and, for the most part, exhausted. The deposits of the USA supplied the greatest amount of this rare mineral.

In Russia, individual findings of it in the emerald mines in the Urals were cornered by Zeiss. Besides the Malyshev mine of the emerald mines, optical fluorite is encountered, it is true, in the form of rare, individual crystals, in the Boev deposit of wolframite in the Urals, the Onon tin deposit in Eastern Trans-Baikalia, in the Aurakhmat deposit in Central Asia, in the region of the Irba River in the Yenisey taiga (lead mine), described by L. Solodovnikov [59].

All of these findings at the present time could not yield any considerable quantities of optical fluorspar.

The vigorous development of optical instrument construction in the USSR during recent years required a considerable quantity of optical fluorite, which was obtained from the Kuli-Kolon deposit, discovered in 1933 by the party of the Institute of Mineral Raw Material and the Tadzhik-Pamir expedition (TPE) on the territory of Soviet Tadzhikistan.

This deposit is located in the south-eastern bank of Kulikolon Lake, in the western spurs of the Zeravshan Range in the Pendzhikent region. Its coordinates are: longitude (from Pulkov) 37 degrees

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50 minutes 49 seconds 7; latitude 39 degrees 15 minutes 41 seconds 3; altitude - 2905.8 meters.

From the station of Samarkand to the town of Pendzhikent it is 62 kilometers by highway; further, from the village of Kshtut, known for its coal mines, it is 55 kilometers by carriage road, which is suitable for auto-transport in the summer; the Kuli-Kolon natural landmark is connected with the village of Kshtut by a pack path 25 miles long, which passes through the narrow ravine of the Urech' River, the right-hand tributary of the Kshtut River.

Fluorite from the region of Kuli-Kolon became known through the indications of the geologist T. N. Ivanov, who worked with the party of the TPE in 1932.

In 1933, the original deposit was discovered and investigated in detail by the party of the Institute of Mineral Raw Material and the TPE, with the participation of the author, whereupon a great quantity of fluorite from this deposit was extracted. In 1934, prospecting was conducted by that same party.

The region in which the deposit is located is a highly eroded high-mountain country, which is characterized by a number of ranges, stretching in a latitudinal direction, from which spurs run out in a meridional direction.

The absolute elevations fluctuate in the small area within the limits of 1860 meters to 5,723 meters.

As a result of tectonic dislocations of a latitudinal trend,

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characteristic of the Zaravshan-Gissar system, the limestones, which compose the mountain ranges, frequently are sharply dislocated and form huge, high, vertical walls, which confine the small valleys.

A thick stratum of limestones and shales, dipping at an angle of 40-55 degrees, imparts sloping forms to the southern side, while at the same time the northern side always crops out in the form of precipitous walls.

In the southern part of the region, in a direction nearly latitudinal, the Chimtarga Range stretches for 20 kilometers; from the north the region is closed up by the Tandin Range.

From these chief orographical units, spurs run out in a nearly meridional direction. These spurs in combination with the precipitous sides of the main ranges create valleys of square forms, at the bottom of which are found glacial lakes.

The natural landmark of Kuli-Kolon is also such a type of valley; it is a broad basin closed on all sides, 3.5 kilometers wide and 5 kilometers long.

From the south, the valley is confined by the sheer walls of the Chimtarga Range and its spurs; toward the east and northeast, the western slopes of the spurs of the Laudan Range rise up. From the north and northwest, the valley is closed in by the Tandar Range and its spurs.

Kuli-Kolon is a basin with an almost horizontal bottom, filled with morainic deposits; the glacier was preserved only in the upper part of the basin, in the Sary-obi-khunuk ravine (glacial cirque).

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Almost all of the southern part of the basin is occupied by Lake Kuli-Kolon, the length of which is 1.5 kilometer, with a width of 0.5 kilometer, fed, chiefly, by melted waters from the Sary-obi-khunuk glacier; it is also the source of the Urech' River.

In spite of the considerable absolute elevation, the majority of ranges during the middle of summer are free of snow, and only the Chimtarga Range remains covered with a thick covering of snow.

A thick layer of metamorphized limestones and shales of Silurian age contains the basic rocks which compose the region; these are accompanied by seams of sandstones, quartzites and graywackes, and by a weakly expressed, within the limits of the plane, argillosandy-conglomerate layer of Mesozoic age. The intrusive complex occupies an insignificant place in the structure of the region, and is represented by quartzitic diorites, dioritic porphyrites, chloritobiotitic porphyrites and aplite-like granite.

The metamorphic stratum has a sustained latitudinal trend and dips to the south at an angle of 40 to 55 degrees, sometimes deviating to 25 degrees; it is crumpled into a complex system of isoclinal folds.

The crystalline, massive, more rarely bedded, Upper Silurian limestones are prevalent in the southern part of the region, composing the Chimtarga Range; in the northern part, they alternate with the shale layer, forming rocky ridges with abrupt sides, which stand out sharply over the shales which more easily yield to erosion, and are traced along a trend of tens of kilometers.

The veins of calcite in the limestones are considerably developed, filling the fractures in them in the most different directions. Their

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thickness fluctuates from part of a centimeter to 2.5 meters.

Among the shales are encountered stratified quartzitic-plagioclase veinlets of irregular form, from 1 centimeter to 0.75 meter thick, conforming to the cleavage of the shales. The latter are highly crumpled and form small folds, frequently passing over into fine plicated folds.

At the contact of the shales with the limestones, in the latter is observed a zone of limestone breccia, cemented by hornstone, but more frequently, the limestones for a considerable distance from the contacts are highly chertized.

The deposit of fluorite, located on the south-eastern bank of Lake Kuli-Kolon, also is coordinated to such a contact of limestones with shales.

The intrusive complex, weakly developed in the region, is represented by a small block (?) of quartzitic diorite, extending in a latitudinal direction in the Zindon valley and covering the limestone-shale stratum, and by an entire series ^{of} apophyses, which penetrated into the latter.

The sulfides are connected with this intrusion, in particular the arsenopyrite at the contact of the intrusion with the limestone covering.

The Mesozoic deposits are represented by an argillo-sandy-conglomerate stratum, crumpled into small folds, unconformably leaning on the Upper Silurian limestones and shales only in the northern part of the region.

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Among the recent formations with a broad development are the fluvioglacial and deluvian deposits.

In the formation of the region are reflected the complex tectonic processes, which were expressed, chiefly, as also for the entire Zeravshan-Gissar system, in a powerful disjunctive dislocation of latitudinal trend. The superimposing of tectonic processes, which followed one after the other, created, as a result, a very complex structure.

The main phase of orogeny, by analogy with the neighboring regions, is variscite, under the influence of which were formed the basic structures and crumpled into isocline folds of latitudinal trend, with a dip to the south, the rocks of the whole stratum of Upper Silurian deposits. On the other hand, to the variscitic orogeny pertain the powerful fault-dislocations of latitudinal and meridional trend, with a dip close to the perpendicular, forming step-like forms of relief and a number of grabens and horsts of the Chintarga type. These dislocations also created a passage for the intrusion of quartzitic-dioritic magma.

Comparatively weakly reflected in the more pliable shales and having caused only in them the formation of micro-folding, the fault-dislocation tectonics were highly reflected in the limestones, forming in them along the line of dislocation a thick zone of breccia, cemented by quartz and more rarely by calcite.

The fluoritic deposit also is coordinated to this zone of breccia at the contact of the limestones with the shales.

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Evidently, by the time of the variscite orogeny, the re-crystallization of the limestones and the transformation of the argillo-siliceous sedimentary stratum of the Upper Silurian age are coordinated to the silico-chloritic-sericitic shales.

Orogenetical movements of the Alpine age, being superimposed on the variscitic movements, complicated the tectonic structure of the region and caused the crumpling of the Mesozoic deposits into sloping folds, having complicated the folding of the Paleozoic deposits, in place⁵ pushing the latter onto the Mesozoic deposits.

The deposit of fluorite, coordinated to the zone of breccia in the limestones, at the contact of the latter with the shales, is found in the Flyuoritov cliff, which forms the south-eastern bank of Lake Kuli-Kolon and is a small spur of the Chimtarga Range. Stretching in a north-eastern direction, the Flyuoritov cliff (Figure 1), 300 meters in length and 120 meters wide near the base, is built up by dark, bituminous marblized limestones, which pass over toward the north into banded limestones. Steeply descending to the lake from the west, in the eastern part the limestones issue from under the thick layer of shales, which connect the cliff with the basic Chimtarga Range.

The south-eastern part of the Flyuoritov cliff rises in the form of a sharp summit, 170 meters above the lake, and falls away abruptly, forming a series of benches.

Variscitic tectonic dislocations, which caused the formation of the brecciated zones in the limestones, simultaneously created passages for the siliceous, fluorine and barium-containing thermal

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springs, which caused the silicification of the limestones and the shales and the appearance of the deposit of fluorite.

Under the influence of these solutions, the limestones of the Flyuoritov cliff were impregnated with quartz, metasomatically displacing them, transforming them into hornstone.

The summit of the Flyuoritov cliff is built up by breccia of limestone, coordinated to the zone of fracture at the contact of the limestones and shales and is traced along the contact, chiefly in the central, highest part of the ridge (Figure 2).

The trend, both of the contact of the limestones with the shales and also of the zone of fracture with the breccia included in it, is not sustained, with an average trend north-east 65 degrees; the dip is south 70 degrees.

The zone of breccia is divided into two strips: the first, coordinated to the contact of the limestones with the shales, is a broken strip of silico-baritic breccia, in the form of a number of lenses 1-2 meters thick, represented by angular fragments of shales and the less numerous fragments of hornstone and limestone, cemented by quartz and barite. The silico-baritic breccia sometimes contains phenocrysts of small grains and crystals of galenite and, very rarely, minute grains of violet fluorite.

The second strip passes through parallel to the first in the limestones, 3 meters from their contact with the shales and represented by chloritic-hornstone breccia (Figure 3), which is comprised of angular fragments of hornstone and highly silicified limestone,

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cemented by fine-grained chloritic hornstone. Sections are encountered, entirely formed by chloritic hornstone, in the absence of fragments of enclosing rocks.

Figure 1. View of the Flyuoritov cliff (x - indicated the deposit; photograph by V. I. Sobolevskiy).

The breccia has numerous cavities of leaching out, which are encountered also in the hornstones and siliceous limestones, forming geodes, crustified with minute crystals of quartz.



Figure 2. Geological cross section of the ridge of Flyuoritov cliff.

1 - crystalline limestones; 2 - chloritic-hornstone breccia; 3 - silico-baritic breccia; 4 - green shales; 5 - tectonic lines.

Between the two strips of breccia are situated pockets of optical fluorite and barite (Figure 4). Three pockets of fluorite are located along the ridge; the first, which yielded the greatest quantity of crystals, is coordinated to an abruptly-dipping fracture of latitudinal trend and is situated among the hornstones on the northeast side of the Flyuoritov cliff; the remaining two pockets are located in succession in the middle and western part of the cliff in the dolomitized limestones and are connected with the fractures of meridional direction.

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Figure 3. Character of chloritic-hornstone breccia.

Natural size.

In the intervals between the pockets of fluorite are located small pockets of barite, frequently transparent.

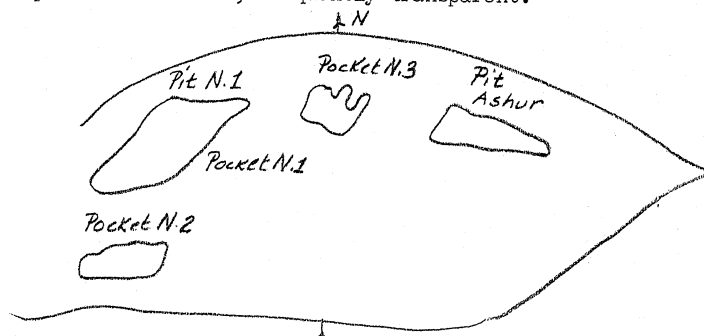


Figure 4. Scheme of the location of pockets of optical fluorite (according to Smolyanskiy).

1 - hornstone and silicified limestones; 2 - chloritic-hornstone breccia; 3 - silico-baritic breccia; 4 - scattered fluorite; 5 - pockets of optical fluorite.

The rocks which enclose and compose the deposit are dark, bituminous, highly quartzitized limestones, gradually passing over into hornstone. These transitions can be noted in the lowering of the intensiveness of chertization in proportion to distance from the tectonic lines; the limestones and hornstones are broken up into a fine cleavage by a complex network of fractures, filled with milk-white quartz.

The largest pocket, No 1, is a body of lenticular form, stretched in a northeastern direction for 8 meters and with a dip

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to the southeast at an angle of 60 - 70 degrees; reaching a thickness in the central part up to 4 meters, it tapers out both along the dip and also along the trend (Figure 5).

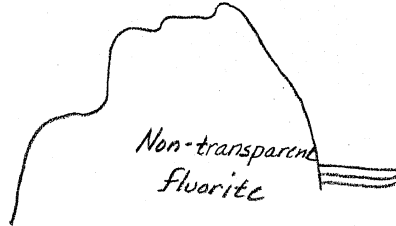


Figure 5. Schematic vertical section through pocket No 1.

1 - hornstone and silicified limestones; 2 - chloritic-hornstone breccia; 3 - silico-baritic breccia; 4 - scattered fluorite; 5 - optical fluorite; 6 - non-transparent fluorite; 7 - chloritic shales.

The pocket is filled with large lumps of highly silicified limestone and hornstone, oriented in conformity with the average trend and dip "of the ore body" and which is the basis on which the crystals of fluorite are located. The maximum width of the lumps reached 70 centimeters, with a height (length) of 1 meter.

The intervals between the lumps in the upper part of the pocket are filled with porous, clay-like material, apparently eluvium brought into the fracture by percolating waters. In the surface part of the pocket, this material is enriched with humus and covers the vegetation.

In the middle part of the pocket, the intervals between the lumps of hornstone are filled with broken stone, and in the lowest part cavities form, filled with freely formed crystals of fluorite.

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The lumps of hornstone and limestone, which fill the pocket, as well as the hornstone which encloses it, in the fractures are filled with quartz, which forms a very fine network. Subsequently, when CaCO_3 was leached out by the silico-fluorine solutions, the very fine siliceous screen was preserved in the form of shell. The surfaces of these screens are crustified by minute crystals of quartz and fluorite.

By the processing of the limestone, which encloses the ore body, with the weak HCl we obtained a well-expressed cellular network, which confirms the course of the process.

In spite of the different location of the druses in the deposit, the arrangement of the crystals in them and their distribution according to sizes is characteristic; the following order is determined for the distribution of the crystals according to their size: in the abruptly dipping walls of the lumps of hornstone, small, 1 centimeter on the edge, crystals of fluorite are located, while at the same time on the overhanging surfaces larger crystals are concentrated; the upper surfaces of the lumps, in the majority of cases, are distinguished by the absence of fluorite or are covered with very small, single crystals.

A similar distribution is noted also with respect to the transparency of the crystals; the milk-white and non-transparent variety matches up with the upper part of the pocket; gradually passing over downwards into the transparent, well-formed crystals.

A similar distribution is noted also with respect to the transparency of the crystals; the milk-white and non-transparent

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variety matches up with the upper part of the pocket, gradually passing over downwards into the transparent, well-formed crystals.

Certain changes of the nature of the fluorite are observed also in the trend of the pocket. The largest crystals are almost entirely concentrated in the southwestern part of the pocket, near the contact with the limestones, whence are extracted the large druses and crystals, which reach 30 centimeters on the edge. In proportion to an advance to the northeast, the sizes of the crystals decrease to 1-2 millimeters.

Figure 6. A crystal of optical fluorite.

Pocket No 2, located in the southern part of pit 1, is distinguished from the first by the nature of the fluoritization; the fluorite is represented here chiefly by semi-transparent and greenish varieties; only in the lower part is found an insignificant quantity of transparent crystals.

Pocket No 3, located 1 meter to the east of No 2, has sizes 2 x 2.5 meters, not differing from pocket No 2 in the nature of filling up.

Deposits No 2 and 3, located in the central and western part of Flyuoritov cliff, as a consequence of their great non-transparency, are of no great interest.

The form of the crystals in all of the deposits is extremely similar (Figures 6 and 7). It is chiefly regularly formed cubes, with a negligible number of combinations; the sizes of the crystals

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are from 1 to 30 centimeters on the edge. The large crystals are found in "free" form at the same time that the druses, which reach sizes 1 meter x 70 centimeters, are covered by crystals from 1 to 15 centimeters in size on the edge.

Figure 7. A crystal of optical fluorite.

The exceptional homogeneity of the material in the deposit and the insignificant fluctuations of the sizes in each individual druse should be noted.

Theoretically, the transparent and large crystals of fluorite of Kuli-Kolon are exceptionally valuable, and the deposit, with a ⁿon-mineral composition and huge crystals, is among the rarest on Earth.

Fluorite yielded by the deposit showed exceptionally high optical properties. Exceptional transparency, high conductivity not only of rays of the visible part of the spectrum but, which is especially important, of rays of the extreme right and left part of it, with complete absence of optical abnormalities, place it among the better varieties ever obtained from the deposits of the world.¹ (¹ For a more detailed treatment of these questions, see the work of V. I. Sobolevskiy and others, Optical fluorite of the Kuli-kolon deposit. Published by TPE.)

It is necessary to note the completely transparent and colorless large crystals of barite which were discovered in the Flyuoritov cliff in individual pockets, up to 10 and even 20 (!) centimeters long,

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completely transparent and colorless crystals of barite. The latter were formed in holes in the limestone and are coordinated, as the fluorite also, to the lumps of hornstone, which fill the holes.

According to the paragenesis of the minerals, the Kuli-Kolon deposit may be referred to the hydrothermal phase of the epithermal zone.

The formation of the deposit, like the presence in the region among the chloritic shales of quartzitic-plagioclase veins, apparently, should be connected with the intrusion of magma, which appears on the surface in the form of quartzitic diorites in the Zindon Ravine and porphyrites in the Rivat Ravine.

The phases of formation of the deposits are depicted in the following form.

The siliceous solutions which ascended in the zone of fracture filled the fractures, partially cemented the breccia and, penetrating into the limestones, created the form of the next "cellular structure," simultaneously displacing them metasomatically and forming hornstone.

Gradually, the changed siliceous solutions were enriched by the sulfides of lead and barium. Then the solutions were enriched by fluorine and yielded a deposit of violet fluorite simultaneously with barite. Finally, the silico-fluorine solutions, deriving calcium from the limestones, afforded the possibility for the fluorite to crystallize in the cavities.

To the next phase of mineralization should be referred the formation of calcite and quartz, which, in the form of small crystals,

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covers the crystals of fluorite and barite. At the very end of the process nacrite was formed, filling the cavities between the druses.

In spite of the exceptional value of optical fluorite, the Kuli-Kolon deposit cannot, in any degree, be considered explored. The small operations carried out here were confined to the prospecting of an insignificant part of the Flyuoritov cliff in its surface part, from which was extracted a considerable amount of valuable material. There is no basis for assuming the absence of such pockets in the deeper horizons of the Flyuoritov cliff.

The outcrops of a similar zone of shattering, enclosing the deposit, filled with breccia, which was found to the northwest of the Flyuoritov cliff, may serve as a basis for the prospecting of optical fluorite over a broader area.

The region of Kuli-Kolon Lake, with regularly organized prospecting operations, apparently, can become the base which will guarantee the optical industry a very important raw material.

USSR [Ukrainian SSR]

V. I. Luchitskiy

FLUORSPAR IN THE USSR

On the territory of the USSR [Ukrainian SSR], fluorspar is encountered almost exclusively in the regions of development of crystalline rocks and only in part in the western borderland of the Donbas, among rocks of Carbonaceous age.

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Manifestations of the presence of fluorspar are observed in the north of the Ukrainian crystalline belt, at Volyna in the area of development of Rapakivi granite and rocks related to it. In the Rapakivi granite, as also in the granophyre granite related to it, developed near Korosten', fluorspar is present usually in the form of small grains, which fill the cavities remaining between the grains of the other minerals. Small accumulations of fluorite of such a nature are observed in the blocks of Rapakivi granite and Korosten' granophyre granite in the region of the northern Malinsk block of Rapakivi and in the central part of the Ukrainian crystalline belt, namely, in the region of the Korsunsk and Cherkassk blocks of Rapakivi in the south of Kiev Oblast, along the Rosa, Olyshanka and Tashlyk rivers and others.

In the south-east of the region of development of the crystalline rocks, fluorspar enters in the form of small grains into the composition of the alkaline granites, normarkites and alkaline syenites, developed along the banks of the Kal-chik and Kal'mius rivers, almost from the shores of the Azov Sea near Mariupol to the Volnovakh station, from the Kal'chik River to the Gruzskiy Yeranchik River. Here, also, the fluorspar fills the remaining intervals between the grains of the other minerals which enter into the composition of these rocks.

Fluorspar is present, in a rather small quantity, in the nepheline-syenites and mariupolites, also filling the remaining intervals, as the last product of the crystallization of the nepheline-syenitic magma. The largest accumulations of it which were observed, which sometimes do not completely fill ~~the~~

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the cavities, reach 1 - 1.5 centimeters in all.

Besides, in the ravine of Vala Tarama in the region of development of the nepheline syenites, formations of fluorspar were encountered beyond the limits of occurrence of the nepheline-syenite rocks.

In the Potapova ravine (Polyakova), which flows into the Shiverov ravine (ravine of the Kal'chik), opposite the Demenikov ravine, P. I. Lebedev observed a vein, nearly 0.25 meter thick, in the mariupolite, formed by a apatite-fluorspar pneumatolyte. Macroscopically, the rock is violet, medium-grained; it consists of rich-violet fluorspar (35.5 percent), apatite (19.5 percent). With them, black, sometimes green, horn blende is paragenetically connected, and also feldspar component parts. The content of F is 17.96 percent; P_2O_5 - 8.10 percent. The vein was not traced along the trend because of the bad erosion.

In the Vala Tarama ravine, in its highly-drawn in right slope, V. I. Luchitskiy discovered a small vein, nearly 0.2 meter thick, formed by rather dense quartz, with dark-violet fluorspar, which forms small, extremely irregularly formed grains and skeletal forms amongst the quartzitic aggregate. The vein also was not traced along the trend.

In addition, in the region to the south-east of the station of Volnovakh, not especially far from the nepheline-syenite massif in the Lower Carbonaceous limestones of the neighborhood of the village of Novo-Troitskiy, near the Sukhaya Volnovakha

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River, small veinlets, up to 1 centimeter thick, of violet fluorspar, which usually taper out quickly, are present. Inasmuch as it is established that the alkaline rocks of the Azov region possess an age which is most likely Hercynian, it can be considered that the fluorspar in the neighborhood of the village of Novo-Troitskiy is connected genetically with the alkaline rocks, most likely with the nepheline syenites.

In 1936, in the region of Volnovakh, geological-prospecting operations were carried out for the purpose of establishing the industrial value of the outcrops of fluorspar already known and searching for new ones.

MINERALOGY OF THE FLUORSPAR

A. L. Ponomarev

The conditions of formation of the numerous deposits of fluorspar in the SSSR [USSR] are exceptionally diverse. Fluorspar, with complete right, may be considered as a poly-genetical mineral, the crystallization of which takes place at the most different temperatures. Fluorspar is present in the form of small impregnations in the magmatic rocks, in the various pegmatites and pneumatolytes; it is encountered in the hydrothermal deposits from hypo - to epithermal,

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MINERALOGY OF THE FLUORSPAR

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Such a great thermal range of crystallization of the fluorspar to a certain degree conditioned the great variety of those mineral combinations in which we find it. Together with topaz, beryl, cassiterite and wolframite, it is encountered in company with the different sulfides -- with cinnabar and antimony glance, and further with barite, kaolinite and other minerals of the cold thermal springs. The nature and composition of the solutions, from which occurred the crystallization of the fluorspar of the different deposits, were extremely diverse and were distinguished from one another not only by a certain temperature range. Those compounds, in the form of which the fluorine travelled from the magma, are very diverse; and also the composition and nature of the fluorine-containing solutions.

No less various are those surrounding conditions, in which takes place the formation of the fluorspar. The different mag-

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matic rocks -- granites, nepheline syenites, basalts and others, the various metamorphic and sedimentary rocks -- limestones, shales, sandstones, etc., are the enclosing rocks for its deposit. Together with these, deposits of fluorspar are formed by means of the filling up of the open cavities and fractures and by means of deep metasomatism of the enclosing rocks.

If the characteristics of the conditions of its formation, which were related above for each individual deposit -- concentrations of solutions, speed of crystallization, pressure, movement of the solutions, etc., are added up, then the variety of different factors which condition the crystallization of the fluorspar will become clear. All of this determines the different properties of this mineral itself.

FORMS OF OCCURRENCE, AGGREGATES AND CRYSTALLOGRAPHIC FORM OF FLUORSPAR

The forms of occurrence of fluorspar in the deposits of the Union are exceptionally diverse. In the magmatic rocks -- granites and nepheline syenites -- the fluorspar chiefly forms a small impregnation; somewhat larger accumulations of it, irregular or ⁿvein-like in form, are encountered in the nepheline syenites. In general, this type of deposit of fluorspar is rare; its crystallization takes place in the pneumatolytic phase; deposits of this type with considerable industrial value are not known.

"In contrast to the usual view, fluorite in the granitic pegmatites is rare; not only is it almost not encountered as a formation of the "nadkriticheskiy" phase, but even in the purely

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pegmatitic, "dokriticheskiy", hot, residual solutions its role normally is not great "1 (¹Fersman, A. Ye "Pegmatites").

The formation of fluorspar, which is encountered in the pegmatites, evidently, also takes place in the subsequent pneumatolytic phase. Among its forms of occurrence in this type, the most common are: the filling of small cavities, frequently leading to the formation of fine crystals, and small veinlets or crusts in the fractures in the pegmatites. Among the crystalline forms in this type of deposit, in a like manner are encountered the cube and octahedron, more rarely the rhombic dodecahedron and trigontrioctahedron. Fluorspar of the first generation is crystallized in the form of octahedrons or cube-octahedrons, on which is formed fluorspar of the second generation, which is crystallized exclusively in the form of cubes.

In deposits of the pneumatolytic type, the fluorspar is developed considerably more broadly. Characteristic representatives of this type are the deposits of tinstone along the Onon River and the Bakuka, Belukha and Moyevka deposits of tungsten. Everywhere, here, the fluorspar forms a small impregnation in the enclosing rocks and micaceous casings of these deposits similar to the impregnations in the magmatic rocks. In the micaceous casings, the fluorspar sometimes forms larger, irregular or lenticular accumulations and in these same casings, toward the center of the vein, rather large, excellently formed crystals frequently accumulate. Well-formed crystals are encountered also in the cavities of quartz, which fill the center of the vein. Here, most often are encountered cubes and octahedrons,

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more rarely rhombic dodecahedrons. The separate crystals are usually confined to one certain form, more often the cube, sometimes to combinations of them. The rhombic dodecahedron is not encountered independently. The sequence of formation of the separate forms, even within the limits of one deposit, is similar, as in the pegmatites: octahedron -- rhombic dodecahedron -- cube. In Figure 1 is shown well how the crystals of cubical form accumulate on the cubo-octahedrons.

Especially prevalent is the hydrothermal type of fluorspar deposit.

In deposits of the mesothermal type, fluorspar is encountered chiefly in the form of unbroken, coarsely crystalline formations, which, together with other minerals, form the ore bodies. Simultaneously, in the wall rocks, chiefly in the limestones, it forms a small, sometimes thick, impregnation. Well-defined crystals are rather often encountered in this type of deposit, accumulating on the walls of the cavities in the basic mass of fluorspar. Among these crystals in like manner both the octahedron and ~~also~~ the cube are frequently encountered. Comparatively rarely do facets of the rhombic dodecahedron appear in both of these types of crystals. Cubo-octahedrons also are common. They all accumulate either singly or in disorderly growths. They are always connected in such a fashion that one of the axes of the third order serves as the standard for the plane of attachment, and one of the trends of cleavage appears parallel to this plane. The sequence of formation of these forms within the limits of a single deposit is always similar --

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the fluorspar of the first generation is crystallized in octahedrons and the subsequent generations in cubes. In certain cases, this is seen plainly, owing to the direct accumulation of some crystals on others, but sometimes it is determined owing to the zonality of the vein or the zonality of the crystals themselves, in which is seen their size in the first place in the facets of the octahedron, and then in the facets of the cube.

Figure 1. An accumulation of crystals of fluorspar of cubical form on cube-octahedrons. Bukuka deposit.

Frequently in this type of deposit, in the fractures, in the ore body or in the cavities, the following deposit of fluorspar takes place from the colder solutions, apparently, already not characteristic of the mesotherms. In the majority of cases, in addition, well-defined crystals are formed, which differ from those described earlier; a characteristic feature of them is their tendency toward the formation of step-like crystals and the appearance on them of different complex combinations of tri^octahedron, hexa^octahedron, and tetra^ohexa^ohedron facets, with a cube at the base. The different combinations of these elements condition several types of these concretions themselves.

To the first, simplest type can be referred the large cubical crystals from the Aurakhmat deposit. They are parallel concretions of large cubical crystals, sometimes weakly drawn out of the strict parallel relative position, which can be considered as single, step-like crystals. The basic form -- the cube -- sometimes is complicated very weakly by the developed facets of

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trioctahedrons and hexahedrons. The facets of the cube frequently have a complex structure, reminiscent of ruin forms.

Figure 2. Botryoidal accumulations of cubical crystals.

The second type of these concretions ^S is the botryoidal accumulations of cubical crystals, observed in the deposits of Murakmat and Sedlov (Figure 2). They are also large, step-like cubical crystals, which are attached by a very small part to the wall of the cavity and hang downwards in the form of a tongue-like formation. On the upper surface of this single step-like crystal, the largest crystals develop, at the same time as on its lower surface are located the considerably smaller forms.

To the third type refer usually the very small, cubical step-like crystals, the mutual arrangement of which determines the general form of the crystal itself in the form of an octahedron. Such formations were encountered in the Sedlov, Takob, Solonech deposits and others. On the vertices of this octahedron are located the largest cubical crystals; along the edges they are of average size and on the facets are the smallest. Frequently, the facets of the cube are complicated by the appearance of the rhombic dodecahedron, tetraoctahedrons and hexaoctahedrons, which develop sometimes so strongly that the facets of the cube are entirely displaced.

To the last type of crystals belongs chiefly the single, small crystals, confined by the facets of the hexaoctahedron sometimes with weakly developed facets of the cube.

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Several forms of occurrence of fluorspar, different from the normal mesothermal formations, are observed in the Suyenga and Amderma deposits, which must be referred to the final phases of mesothermal activity. These differences, apparently, are conditioned by the deep metasomatism of the enclosing rocks during the crystallization of the solutions. In both deposits, the fluorspar, together with an impregnation in the enclosing rocks, forms large, unbroken accumulations. The distinguishing characteristic of them is the extreme compactness of the grain of the fluorspar aggregate, owing to which there is no possibility of observing the octahedron cleavage in the individual grains; the ores of these deposits possess also a banding, conditioned by the alternating arrangement of the bands of fluorspar of different transparency. Well-defined crystals are not known at all in the Suyenga deposit, and in the Amderma deposit are encountered in the form of cubes in the calcitic-quartzitic veins.

Figure 3. Columnar varieties of fluorspar, the separate rays of which are completed with the formation of cubical crystals.

For the epithermal deposits of fluorspar, the tendency of this mineral to form columnar varieties and more rarely impregnations or small accumulations among the other vein minerals is very characteristic. Well-developed crystals in this type of deposit are encountered extremely rarely. In the majority of cases, the individual rays of columnar fluorspar are completed by the formation of cubical crystals (Figure 3), sometimes complicated by octahedron facets, a rhombic dodecahedron and trioctahedron, and very rarely they are confined by octahedral crystals.

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The development of these rays is always in the direction of one of the axes of the third order, which conditions the development to its termination of only three facets of the cube adjoining the vertex of the crystal, through which this axis also passes.

In this type of deposit, similarly to the mesothermal types, the formation of fluorspar from the subsequent solutions, the deposit of which takes place in the fractures or in the cavities of the fluorspar which had been precipitated earlier, *is often observed.* In certain cases, these formations are completely identical, similar to deposits of the last mesothermal generations. Here, also, are encountered cubical step-like crystals, with highly developed vicinal facets, the general arrangement of which determines the octahedron itself. In certain cases, such concretions consist of minute hexaoctahedral crystals. Separate hexaoctahedral crystals also are encountered. Sometimes, nodular or stalactite-like formations, consisting of minute cubical crystals, which are found in disorderly concretions, are observed. These cubical crystals sometimes form fine crusts.

The form of the crystals of "rotovkit" -- fluorspar which is encountered always in the "podmoskov" limestones -- is the cube, which accumulates in the cavities of the limestones (Figure 4).

Figure 4. Fluorspar ("rotovkit"), which accumulates in the cavities of the limestone.

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From the data presented, relative to the occurrence of crystallographic forms of fluorspars in deposits of different genetical types, it can be seen that the temperature of formation does not determine the forms of the crystals themselves. Both the cube and the octahedron are encountered in deposits, which were formed at different temperatures. It is evident that the form of the crystals is determined by a whole complex of diverse factors, which it is impossible to take into consideration in the majority of cases. It is possible to establish the sequence in the formation of the different forms: octahedron -- rhombic dodecahedron -- cube -- the different complex step-like crystals with tetrahexahedral, trioctahedral and hexaoctahedral facets, with a cube at the base. A reverse sequence in the formation of these forms was not observed. The only exception to this rule is the absence of one or several forms in certain deposits. The attachment of the crystals of fluorspar in such a fashion that one of the axes of the third order serves as a standard to the plane of accumulation also remains invariable.

CHEMICAL COMPOSITION

Fluorspars of the deposits of the Union have been studied from the chemical side very little up to the present time. Together with the enormous analytical material of fluorspar ores, analyses of pure fluorspar are almost entirely lacking. Below we cite a table of analyses of fluorspars, carried out in recent years by different investigators and only partially published up to the present time. (Table 1).

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In both analyses of the Kuli-Kolon deposit, the absence of Na_2O , K_2O , Li_2O , TiO_2 , BaO , MnO , MgO and H_2O (hygroscopic) was stated.

In the table cited, in the analyses in which fluorine was determined independently, attention is drawn to the discrepancy contrary to the theoretical formula in the ratio between calcium and fluorine. Almost everywhere there is a considerable abundance of fluorine, amounting to 1 percent. In the foreign literature, there are indications of the occurrence in the fluorspars of free fluorine, but always in limited quantities; in the given case it is difficult to consider all of the surplus fluorine as free. On the other hand, it is uncertain that this fluorine is found in connection with any other element, and, evidently, that such a great discrepancy in the ratio of calcium and fluorine must be explained chiefly by an error in determining the fluorine and, possibly, only in small degree by the presence of free fluorine.

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Table 1

Analyses of Fluorspars

	Analyses of N.A. Smol'yaninov						Analyses of P.P. Pilipenko						Analyses of A.P. Burov					Analyses of V.I. Sobolevskiy		
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX
Ca	51.25	51.30	51.38	51.43	51.26	51.16	51.13	50.96	47.73	50.29	38.20	41.61	42.46	42.77	51.00	51.08	50.17	51.16		
F	49.53	48.43	49.10	48.95	49.63	49.24	48.50	48.34	45.25	48.71	36.80	39.60	39.96	41.03	48.48	48.54	45.25	48.20	99.96	99.95
SiO ₂	0.09	0.13	0.04	none	none	none	0.07	0.35	6.93	0.13	10.31	6.57	6.23	4.51	0.02	0.03	0.09	0.60	0.003	0.008
Al ₂ O ₃	0.03	0.16	0.05	0.04	0.26	0.39	0.27	0.05	0.24	0.17	7.25	7.48	6.68	6.50	none	none	0.35	0.35	0.020	0.022
Fe ₂ O ₃	0.01	0.02	0.01	0.02	0.02	0.12	0.02	0.01	0.02	0.03	0.49	0.02	0.02	0.01	none	none	0.021	0.030	0.021	0.030
BaSO ₄	none	none	none	none	none	none	none	none	none	none	none	none	none	0.38	none	none	none	none	----	----
P ₂ O ₅	----	----	----	----	----	----	none	none	traces	none	traces	traces	traces	none	----	----	----	----	----	----
S	----	----	----	----	----	----	----	----	----	none	0.03	none	none	----	0.06	0.01	0.02	0.07	----	----
H ₂ O at 1																				
105°	0.07	0.02	0.03	none	0.06	0.04	----	----	----	----	----	----	----	----	----	----	----	----	0.013	0.012
P.p.p.	0.22	0.02	0.09	none	0.01	0.01	0.04	0.04	0.04	0.34	6.74	4.59	3.94	5.66	----	----	----	----	----	----
CO ₂	none	none	none	none	none	none	none	none	none	none	none	none	none	none	0.04	0.05	1.97	0.07	----	----

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Table 1 (continued)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX
[Totals]	101.20	100.08	100.70	100.44	101.24	100.96	100.03	99.75	100.23	99.67	99.82	99.87	99.29	100.90	99.60	99.71	97.83	100.49	100.01	100.02

F, com-

puted on ba-

sis of Ca.. 48.62 48.60 48.74 48.77 48.60 48.53

Sum, with F

computed on

basis of Ca 100.29 100.31 100.12 100.20 99.86 99.69

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Note. I - Khaydarkan, dark-violet; II - Khaydarkan, light-colored; III - Aurakhmat - dark-violet; IV - Aurakhmat - light-green; V - Badam, almost colorless; VI - Badam, dark-violet; VII - Kalanguy, smoky, columnar; VIII - Kalanguy, columnar, rose-colored; IX - Kalanguy, white, close-grained; X - Abagaytuy, brown, radial; XI - Abagaytuy, close-grained, white; XII - Abagaytuy, close-grained, white; XIII - Abagaytuy, close-grained, white; XIV - Abagaytuy, close-grained, white, with barite; XV - XVIII - Suyenginsk deposit; XIX - Kuli-Kolon, colorless; XX - Kuli-Kolon, aquamarine.

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Unfortunately, direct evidence of the latter in the fluorspars of the deposits of the Union have not been conducted.

The presence in the analyzed samples of such compounds as SiO_2 , Al_2O_3 , Fe_2O_3 , etc., is explained, on the one hand, by the insufficient purity of the material selected for analysis, and on the other hand, by the presence of numerous inclusions in the fluorspar.

Exceptionally interesting work on the analysis of the content of scattered elements in certain fluorspars of the Union was conducted by I. P. Alimarin and R. Ye. Arest-Yakubovich. They analyzed six differently colored samples of fluorspar from the Abagaytuy and Aurakhmat deposits.

Of 29 elements, which have been determined in these samples, Li, Na, K, Sr, Be, Cu, Al, Fe and S were stated. The presence of Na, Cu and Sr the authors of this work explain as an isomorphic change of the ions of calcium, but the remaining elements, in their opinion, are found in the fluorspar in a dispersed state.

Inasmuch as all of these elements were stated in the fluorspars of different color, the authors arrive at the conclusion that the color of the fluorspar does not depend on the presence of the dispersed elements and, evidently, is connected with the presence of the dispersed particles of calcium in the crystalline lattice of the fluorine calcium.

V. I. Vernadskiy indicated the occurrence of sodium and lithium in the Klichkinsk fluorspar.

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In a conversation with K. A. Nenadkevich, he related to us the occurrence in several fluorspars of the Union of mercury as an element, isomorphically displaced by calcium, and also the occurrence of manganese and chlorine. The latter always is present in the fluorspars of brownish or greenish color.

We analyzed several samples of fluorspar from the pneumatolytic deposits for the content in them of yttrium, with negative results.

In addition, it is possible to point out the possible content in the fluorspars of hydrocarbons. The attention of investigators a long time ago was drawn to the rather considerable loss during calcination of fluorspars and their fragrance during crushing. Later, in certain fluorspars of foreign deposits, by the analytical method the presence of hydrocarbons was demonstrated, by which also was explained in certain cases the indicated phenomena.

In the majority of cases, the fluorspars of the deposits of the Union, in different degrees, also show a loss during calcination, which is explained by the presence of different gaseous inclusions. Certain fluorspars of the Union, during crushing or pulverization, disclose a sharp and unpleasant odor, which permits the assumption that there are hydrocarbons in them.

It is interesting that all of the fragrant fluorspars have a bright color, chiefly in violet tones, and are formed in the area of occurrence of limestones, directly in the contacts with them or else metasomatically displacing them. Such dark-violet fluorspars

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are those of Khaydarkan, Badam, Amderma and others; they are all hydrothermal. In the pneumatolytic fluorspars, although also with bright violet coloring, ~~in the pneumatolytic fluorspars, although~~
~~with bright violet coloring~~ of the nepheline-syenite and stannic-tungsten deposits, no fragrance is observed.

COLOR

The color of fluorspars of the deposits of the Union is extremely various. Almost all of the colors of the spectrum are observed among its colors. The most prevalent are green and violet of the most different shadings. More rarely, but still often, colorless fluorspars are encountered, and also rose-colored and light blue. Dark blue and reddish colors are encountered very rarely.

In the majority of cases within the limits of one deposit, there are variously colored fluorspars. They are distributed in the ore body or completely unsystematically in the form of individual sections or patches or strictly regularly in the form of parallel zones, conditioning by these zones the banded structure of the veins. The alternating arrangement of the differently colored bands leads to the formation, zonally, of colored crystals. This zonality most often follows the facets of the octahedron, more rarely the cube. Sometimes, cubical crystals have a zonality conforming to the octahedron. Reverse relationships were not observed. Comparatively often, colorless crystals of fluorspar, chiefly of cubical form, also are encountered, within which are located thin bands of colored fluorspar. Usually, these bands

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are oriented along the facets of the octahedron, more rarely along the facets of the cube and pyramidal cube.

The color of the fluorspars in the majority of cases within the limits of one crystal, if it is not zonal, is distributed uniformly, but sometimes it is seen even with the naked eye, as it is concentrated in some points, which are closely located one to the other.

The color which appears on the surface of the crystals of fluorspar is of great interest. On the facets of the freely growing crystals of colorless or colored fluorite, small specks of violet color are located. As a rule, they are found either on the corners or edges of the crystals or at places of "skol," or some other deformation on their surface. A similar violet color is observed sometimes near the fluorspars and in that case when some minerals are crystallized on its surface. At the place of their attachment, a small violet speck also appears. In the Solonech deposit, the breccia-like fragments of fluorspar, which are cemented by adular and quartz, also produce such a color. On its surface, primarily of green fragments, a fine film of violet fluorspar, as it were, appears. The formation of these colors, undoubtedly, bears a secondary character; their formation took place after the crystals of fluorspar were formed.

The distribution of the differently colored fluorspars according to deposits of different genetical types does not permit the establishment of a connection between the temperature of formation of the fluorspars and their color. The contrary of the

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existence of this connection is indicated by the different sequence of formation of the colored fluorspars in the individual deposits and the presence of zonal crystals with repeatedly alternating colored bands. The dependence between the form of the crystals and their color also is absent. For example, cubical crystals are often colored equally both in green and also in violet color, and in the Kuli-Kolon deposit completely colorless cubes are known.

Still, in certain cases, the conditions of formation of the fluorspar, undoubtedly, determine the appearance of one or another color. Thus, all the fluorspars which form an impregnation in the limestones are colored in violet. But such violet color appears in the casings and larger bodies of fluorspar occurring in the limestones.

In the pneumatolytic, stannic-tungsten deposits, green coloration of the fluorspars is absent. Small grains and small accumulations are formed, primarily, always in the micaceous casings of these deposits, after which its completely colorless crystals are precipitated out. The fluorspar of the nepheline syenites is colored in violet or rose, and sometimes is colorless.

In the majority of cases, the color of the fluorspar is unstable, and under the influence of sunlight rather quickly lightens. This fading generally takes place only a certain time from the moment of carrying the sample out into the sunlight up to the known limit of retention of the color, after which it is transformed. The degree and speed of fading of the fluorspars is different in the different deposits; the green fluorspars of the Takob deposit and Sedlov deposit literally fade before the eyes.

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Together with this exist the stable colors, which do not change under the influence of the sun's rays; of such, apparently, the majority are of dark-violet colors. Certain fluorspars of light-violet color fade to rosy tones (Abagaytuy).

A more intensive fading of fluorspars is observed during the heating of them within the range, approximately of 200-250 degrees. Depending on the primary color, any fluorspar, after 3-10 minutes of heating at the indicated temperatures, becomes colorless. Transitions from one color to another during the process of decolorization are not observed. Only the dark-violet fluorspars become rose-colored at first and then colorless. This decolorization of the fluorspars by means of heating almost always is accompanied by the occurrence of luminescence, the beginning of which coincides with the beginning of decolorization, and the conclusion takes place somewhat later than the complete decolorization of the fluorspar. After the cooling of the fluorspar, it remains colorless, and the primary color does not appear again.

From the literature, it is known that certain fluorspars under the influence of ultra-violet rays also change their color in the direction of discoloration. Two samples of fluorspar -- green from the Sedlov deposit and violet from the Aurakhmat deposit -- were decolorized by us by means of ultra-violet rays during the course of extraction. Both samples showed a bright bluish-violet luminescence, but a noticeable change of color did not set in, probably because of the brief exposure.

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In a similar manner to the decolorization of the fluorspars, it is also easy to cause artificial coloration in them. In case of its exposure to cathode rays, fluorspar of any primary color or else preliminarily decolorized is colored in a dark-violet color. This color is located only on the surface of the lamina or grains of fluorspar, not penetrating into it. The first noticeable appearance of it sets in after 5-10 minutes of exposure with a 3 A current and voltage of 10,000 V.

The action of rays of radium on the colorless fluorspars or the fluorspars preliminarily discolored by heating, outside of their relationship to the primary color, cause the appearance of bluish, dark blue or greenish colors, which penetrate deep into the crystals. The time of appearance is different for the different fluorspars. In some it emerges several hours after decoloration, in others after several days. Also dissimilar is the degree of intensity of the color, which appears near the different fluorspars. Certain naturally colored fluorspars do not completely change their color as a result of the action of radium rays; others -- green and yellow fluorspars -- only increase the intensity of the color, and, in rare cases, change the shadings. Thus, a transition of rose-colored fluorspar into green was observed.

In general outline, X-rays cause a similar coloring in the fluorspars, only weaker.

The change of the color of the fluorspars takes place also as a result of pressure. The powder of green fluorspar from the

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Solonech deposit, after a pressure of 8,000 kilograms per 1 centimeter, was pressed into a very fragile, non-transparent leaf, on the surface of which appeared a scarcely noticeable speck of violet color.

The reasons for the coloring of the fluorspars are explained at the present time by the disturbance of the connection of the ions of calcium and fluorine in the crystalline lattice of the fluorspar itself and the appearance of the "atomarnyy" calcium, the different degree of dispersion of which and the size of the particles also determine the appearance of the various colors. However, to assume the appearance of natural colors near the different fluorspars, under the influence of radio-active radiation is not always possible. For certain cases it is extremely probable, but in others demands some explanation.

LUMINESCENCE

The capacity of certain fluorspars to brighten under the influence of different causes has been known for a long time. Owing to different factors which cause this luminescence, the following types were distinguished: fluorescence, actinoluminescence, trimboluminescence, thermoluminescence and others. Certain of these forms of luminescence were studied by us in samples of fluorspar from deposits of the Union.

The phenomenon of fluorescence was noted only for fluorspar from the Sedlov deposit. Its crystals of brightly emerald-green color in the rays which pass through, in reflected light appeared bluish-violet. This exceptionally strongly expressed property of

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it gradually was lost with the decoloration of its green color after lying for a long while in the sunlight.

Trimboluminescence was observed in a very weak degree during the pulverization and crushing of the following fluorspars: from Olovyan -- colorless, from Sedlov -- green fluorescent, from Solonech -- green together with violet. The absence of this phenomenon was stated near the Kuli-Kolon colorless and Kalanguy columnar fluorspars.

Actinoluminescence is expressed more clearly by the fluorspars from Olonyan -- by the colorless, from Boyevka -- also by the colorless and from Sedlov -- by the green. In the first two cases, after a five-minute exposure from a strong source of light, the samples of fluorspar emitted a bright and lengthy pale-green luminescence. In the last case, the luminescence was considerably weaker and had a bluish shading.

Cathode-luminescence is luminescence under the action of cathode rays and is observed in various degree in almost all of the fluorspars.

The phenomenon of thermoluminescence is sharply expressed by almost all of the fluorspars. Luminescence is observed at temperatures of 200-250 degrees, and after cessation and cooling does not recommence during subsequent heating. The nature, duration and brightness of the luminescence is different for the various fluorspars.

On the basis of the investigations carried out, two

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conclusions can be drawn: (1) the nature of the luminescence is not related to the primary color of the fluorspar and (2) all pneumatolytic, high-temperature fluorspars shine with a bright green color and all hydro-thermal fluorspars with a light-blue, dark-blue and violet color. The lowest temperature formations of fluorspar -- columnar varieties -- are almost devoid of the capacity to shine.

OPTICAL PROPERTIES

The optical properties of fluorspars from the deposits of the Union have been very little studied.

The determination of the index of refraction for the differently colored samples was carried out by us. Three samples were analyzed: (1) -- Kuli-Kolon -- colorless with the transparency of water; (2) -- Sedlov -- bright emerald green and (3) -- Kuli-Kolon -- rich violet. The result of the determination in all cases was identical: $n_{1.434}$. It is interesting that Wulffing, in his time, who conducted determinations of the index of refraction, established the average $n_D = 1.43381 \pm 0.00004$. The extremely weak force of double refraction, which often exceeds 0.00005, was noted by us for the following fluorspars: Kuli-Kolon -- colorless, Olovyan -- colorless, Sedlov -- colorless, rose and green, Abagaytuy -- bluish-green, Solonech -- green, Aurakhmat -- colorless and pale-violet and Kalanguy -- columnar of different shadings. In the majority of cases, the abnormalities are located near minute fractures and have the form of straight, indistinct lines, with

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unequal outlines. More rarely, these abnormalities are located near the seams between the junctures of the different grains of fluorspar.

P. P. Pilipenko reports optical abnormalities for the Kalanguy deposit in the columnar fluorspar; the abnormalities have the form of honey-combed networks or mossy meshings. The main lines of these abnormalities were directed perpendicularly to the facets of the cube, and the less visible were directed parallelly to it. P. P. Pilipenko considers as the reason for their appearance the tensions originating during the time of development of the columnar fluorspar.

SPECIFIC GRAVITY

All determinations of specific gravity of fluorspar were carried out with the aid of a specific gravity flask on small fragments. Of twenty-one determinations, eighteen were carried out by us and the remaining three were done independently by N. A. Smol'yaninov.

The average specific gravity of the 21 determinations equals 3.1806, with fluctuations from 3.1736 to 3.1904.

The relatively small fluctuations which are observed for individual samples must be explained chiefly by the presence in them of inclusions both of gasses and liquids and also of separate minerals. In certain cases, such a relation emerges very clearly. For example, the banded fluorspar of Suyenga, which contains an extremely large quantity of minute inclusions of gasses, shows a specific gravity considerably lower than the average; on the contrary, the dark-violet fluorspar of Amderma, which is found in

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paragenesis with chalcopyrite and, possibly, containing it in a quantity of minute inclusions, possesses a specific gravity exceeding the average figure.

RADIOACTIVITY

From the foreign literature it is known that many fluor-spars are weakly radioactive, independently of their color. Apparently, radioactivity is not inherent in the fluorspar itself, but is caused by the presence in it of admixtures or inclusions of minerals.

We investigated the following samples of fluorspar from the deposits of the Union for radioactivity: Solonech - brightly emerald-green, Abagaytuy -- brightly bluish-green, Takob -- brightly bluish-green, Aurakhmat -- brightly violet, Sedlov -- pale-rose, Kalanguy -- pale-rose, Konduy -- dark-violet, Olovyan -- colorless, watery-transparent, Suyenga -- banded, pale-greenish, Amderma -- small-grained, compact, milk-white.

They all produced negative results.

LOSS ON CALCINATION

The fact of loss of weight of fluorspars during calcination has been known for a long time. As early as 1845, Bol'yef reported that green phosphorescent fluorite from the Urals decreased in weight by 0.0416 per cent during heating.

Several samples of fluorspar were analyzed by me for loss of

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weight during calcination up to 300 degrees. The results are shown in Table 2.

Table 2

No. in Order	Deposit	Characteristics of the	Loss during Calcination
		Fluorspar	
1	Kuli-Kolon	Colorless, watery-transparent	0.0176
2	Kuli-Kolon	Colorless, cloudy	0.0427
3	Takob	Bright-green, weakly transparent	0.0395
4	Kalanguy	Rosy, columnar, transparent	0.0302
5	Konduy	Dark-violet, weakly transparent	0.0361
6	Aurakhmat	Bright-violet, transparent	0.0307
7	Anderma	Colorless, close-grained	0.0368
8	Olovyan	Colorless, watery-transparent	0.0403

From the table it can be seen that for the majority of fluorspars the loss during calcination is equal to approximately 0.03 per cent. Sharp deviations from this figure are shown by the two samples from the Kuli-Kolon deposit. The first of these is completely transparent, but the second is cloudy and during an investigation under the microscope shows a huge quantity of minute drop-shaped inclusions of gasses and liquids, which are almost completely absent in the first sample. But such a large content of these inclusions is observed also in the colorless fluorspar from the Olovyan deposit,

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which also shows an increased figure for loss during calcination. No connection between the loss in weight and the color and conditions of formation of the fluorspars is observed. Both the watery-transparent fluorspar from Kuli-Kolon, which was formed from cold thermal solutions, and also the fluorspar from the Olovyan deposit, which possesses a pneumatolytic genesis, show approximately a similar, somewhat increased loss in weight during calcination, and, as shown earlier, contain a large quantity of inclusions. The nature of these inclusions was not analyzed. To attribute all of them to the hydrocarbons is scarcely possible.

PSEUDOMORPHS

The formation of pseudomorphs by fluorspar in some minerals is a rather rare occurrence for the deposits of the Union. It is possible that the occurrence is developed considerably more widely, but this has not been studied with great care up to the present time.

Most frequently, the fluorspar forms pseudomorphs in calcite. They are known with authenticity for the Takob and Abagaytuy deposits. In both cases, the fluorspar not only adopts the primary structure of the aggregate of calcitic grains, but in it are preserved lines in the form of fine fractures, which correspond to the cleavage of the calcite.

The pseudomorphosis of fluorspar in calcite or barite was reported for Taminga III deposit.

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Pseudomorph⁹ses are observed in the Abagaytuy deposit in the guise of fluorspar in barite. In the Takob deposit there is a not completely definite displacement of the quartz by the fluorspar.

A very interesting pseudomorphic displacement of the needle-shaped antimony glance by the fluorspar is shown by V. P. Rentgarten for the Boguchan deposit.

Still more rare are the pseudomorphoses of some minerals in the fluorspar. The displacement of it by quartz only is established. In certain cases, its cubical forms are adopted completely by this mineral, but more frequently the quartz displaces its crystals only along the periphery, as if growing into it. Pseudomorphoses of quartz in the fluorspar are prevalent. Complete pseudomorphoses of such a nature were observed at the Taminga, Khaydarkan and Takob deposits.

INCLUSIONS

Different inclusions in the fluorspars are extremely prevalent. Crystals of fluorspar without inclusions is, in general, a rather rare occurrence.

One of the minerals most frequently included in the fluorspar is quartz. It is encountered in almost all of the deposits. The forms of its inclusions are rather diverse. Very frequently, it forms minute, elongated grains, which are situated in the crystal of fluorspar without any regularity. But sometimes they are oriented with the long axis in the cleavage. No less rare are the formless inclusions of quartz. The inclusions of it in the form of a thick

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network of very fine veinlets running along the plane of the octahedron, are interesting.

To the number of rather frequently observed inclusions pertain also the various argillaceous products, which, in the form of dust-like particles, are found in the fluorspar. Sometimes, the different thickness of these inclusions determines the lines or zones themselves in the crystals of fluorspar, apparently dependent on its development and corresponding to the facets of the cube.

Inclusions of the various sulfides in the fluorspar also are common. Now and then they are located with an orientation following definite directions in the fluorspar, in the majority of cases corresponding to the facets of the cube. Inclusions of liquids and gasses are extremely prevalent in almost all of the crystals of fluorspar, outside of the relation to the conditions of its formation. Sometimes it is a rather thick and completely irregular impregnation of minute, literally a point, inclusions. Their form is most diverse. In these cases, they frequently fuse together, forming elongated channels; their sizes are extremely diverse. Very rarely, inclusions of gasses, up to 3 millimeters in diameter, with an average from 0.1 to 0.01 millimeter, were observed. The nature of these inclusions is not clear. It is possible that in the fluorspars which are formed in the limestones and, in particular, which possess odors, the drop-shaped inclusions of liquid are represented by hydrocarbon compounds.

The quantity and thickness of these inclusions in the fluorspar frequently determine its transparency. Thus, for example, the

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cloudiness of certain Kuli-Kolen crystals of optical fluorspar, the weak transparency of Aurakhmat crystals and the bandedness of the Suyenga fluorspar are conditioned chiefly by the large quantity of these inclusions.

DECREPITATION

The majority of fluorspars possess the capacity during heating to crack. This property is expressed in different degree not only for the different deposits, but frequently in the limits of a single deposit. The temperature at which this process takes place is approximately near 200 degrees, with a slight deviation to one side or the other. In certain cases, this process of decrepitation takes place so intensively that pieces of fluorspar literally disintegrate with a snap and with force -- scattering into minute particles.

The capacity of fluorspar to crack during heating is connected with the presence in it of numerous inclusions of liquids. The correspondence of the temperature of decrepitation and the boiling point of certain hydrocarbons enabled several investigators to draw the conclusion that the majority of liquids which are found as inclusions in the fluorspars do belong to the hydrocarbons.

Analyses showed that any direct relation between decrepitation and the conditions of formation of fluorspars is not observed. All of its fine-grained varieties and columnar varieties were decrepitated considerably more weakly than the coarsely crystalline varieties.

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CONCENTRATION OF FLUORSPAR

M. A. Eygeles

BASES OF CONCENTRATION OF FLUORSPAR

Fluorspar and its Technical Specifications

Fluorspar is widely used in a number of the most important branches of industry [50, 52]. In connection with this, one of the basic questions, which demands a clear answer for the correct solution of the task of primary dressing (concentration) of the fluorspar ores of the deposits of the USSR, is the determination of the technical specifications for the different applications of it.

In spite of the considerable volume of demand for fluorspar in the Union, up to the present time, in determining the technical specifications, a number of confusions have arisen. This is explained not only by the insufficient study of the conditions of utilization of fluorspar and the relative youth of the branches of industry requiring it -- the production of cryolite, fine metallurgy -- but still in large degree by the fact that the concentration industry for fluorspar is found now in the stage of organization and construction. The consumers, to a large degree, were obliged to orient themselves to the modest possibilities of the fluorspar industry, accommodating themselves to the re-processing and utilization of fluorspar of low quality. With the starting of concentration plants for fluorspar, the situation is changing sharply and the consumers are presenting demands to obtain high-quality, completely conditioned varieties of fluorspar. In

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connection with this, the technical specifications of the foreign, chiefly American, practice ^{are} of considerable interest.

In the consumption of fluorspar in foreign practice, apart from the content of CaF_2 , depending on the individual forms of applying the fluorspar, the content of the following admixture also is conditioned: silicon dioxide (SiO_2), barite (BaSO_4), calcite (CaCO_3), ferrous oxide (Fe_2O_3), manganese (Mn), heavy metals -- lead (Pb) and zinc (Zn) -- and sulfur (S).

In the United States [50], metallurgy employs fluorspar in pieces or in the form of gravel with a content of CaF_2 of not less than 85 per cent. The content of quartz usually comprises 5-6 per cent and must not be more than 10 per cent.

Metallurgy employs fluorspar in pieces of gravel the size of which is from 3 to 15 millimeters. The granulometric composition of the fluorspar, according to the data of Rider, is cited [57] in Table 1.

Certain amounts of fluorspar are employed in metallurgy, chiefly in the production of alloys and in electrosmelting, in the form of powder.

Table 1

Size, "Mesh"	Yield of Grade in Percent	Size, "Mesh"	Yield of Grade in Percent
+3	19.28	+60	27.76
+14	46.82	-60	6.14

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For the production of fluorine salt by the acid method, the chemical industry requires fluorspar of high quality. The content of calcium fluoride in it must be not less than 97 percent, with a content of silicon dioxide of not more than 2 percent. With regard to the size of this variety of fluorspar, any lump form, as well as the ground product, is permissible for the chemical industry.

The vitreous variety is employed also in the ground form. Davis gives the following average chemical analyses for the different varieties of fluorspar (Table 2).

Table 2

Chemical analysis of individual varieties of fluorspar

		Content in Percent						
		CaF ₂	SiO ₂	CaCO ₃	Fe ₂ O ₃	Al ₂ O ₃	S	BaSO ₄
Production of steel		87.50	4.00	7.20	0.60	0.55	0.12	----
		87.80	3.10	---		3.06	----	----
		88.92	3.07	1.23	----	----	1.96	4.16
Foundry work		82.00	8.00	1.30	----	----	----	----
		87.00	4.50	7.50	----	----	----	----
		92.00	3.50	3.67	----	----	----	----
Glass and		95.00	2.50	---	0.12	----	----	----
Enamel Industry		97.40	1.55	0.54	0.14	0.26	0.03	----
		98.53	0.76	0.37		0.34	----	----
Chemical Industry		99.07	0.24	0.38		0.29	0.02	----

The technical specifications brought out above are the

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average most typical for the fluorspar industry. Individual consumers frequently depart from these specifications, which are conditions of the commercial varieties, and not a standard.

The technical specifications for fluorspar from our deposits at the present time are only beginning to be established. The standard for fluorspar of manual concentration provides for the output of three varieties of fluorspar.

A certain instability of technical specifications for fluorspar was reflected in the plans for concentration plants. Thus, the oldest of the plans for the Aurakhmat concentration plant provides for the output of three varieties of fluorspar: the lump variety, with a content of CaF_2 of 90 percent, the crushed I variety, with a content of CaF_2 of 95 percent, and the crushed II variety, with a content of CaF_2 of 70 percent.

The old plan for the Kalanguy concentration plant exactly in the same way provided for the output of three varieties of fluorspar: the lump variety, with a content of CaF_2 of 85 percent, crushed variety I, with a content of CaF_2 of 97 percent, and crushed II variety, with a content of CaF_2 of 90 percent.

The plan of the Amderma concentration plan provides for the output of fluorspar with a content of CaF_2 of 95 percent. The plan of the Takob concentration plant provides for an output of fluorspar with a content of CaF_2 of 95-96 percent and of SiO_2 of 2 percent.

Only in the last plans -- Amderma and Takob -- is the content of several of the admixtures in the fluorspar conditioned.

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Existing obscurities in the technical specifications for fluorspar hinder the correct development of its concentration. It is completely clear that the fluorspar industry of the USSR cannot proceed from the present foreign practice of the United States or other countries. The specificity of the ores of our deposits, frequently rich in quartz at the same that the American deposits, for example, are rich in calcite, the considerably higher specific gravity of the consumption of superior varieties, the remoteness of the fluorspar enterprises from the centers of consumption of the country, on the one hand, and, on the other, the absence of competition and the possibility, from the point of view of the interests of the national economy, of the correct solution of the question of the optimum quality of the raw material, compel us to concern ourselves attentively with the technical specifications for fluorspar and to develop them independently, taking into account our natural and economic characteristics.

For the chemical industry, the high quality of the fluorspar means an increase in the output of the plants, the improvement in the quality of the fluorine compounds, and less wear and tear on the equipment. For the matter of concentration, the determination of the exact technical specifications may be materially reflected in the plan of concentration, its character, possibly, even its methods, on the nature of the reagents chosen for flotation, etc. Complete clearness in the technical specifications guarantees the most correct solution of the task of primary dressing of the fluorspar and the quickest, painless development of the fluorspar concentration industry.

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The practically acceptable technical specifications for the consumers at the present time, even though incomplete, are set forth in Table 3.

Table 3

Technical specifications of fluorspar in the USSR

Kind of industry	Content of CaF ₂ in % (not less)	Content of admixture in % (not less)	Granulometric characteristics
Metallurgical	75-85	S - 0.3	lump and gravel
Acid (chemical)	95-96	-	lump and crushed
Enamel	95	Fe ₂ O ₃ - 0.12	lump and crushed

The fluorspar of our deposits, for the most part, do not satisfy these requirements.

Detailed samplings of our deposits show that the basic reserves are comprised of ore in which, together with fluorite, considerable quantities of barren rock, and sometimes other useful minerals, are present.

The ordinary ore, according to the content of the fluorite and permissible limits of the content of admixtures, in the majority of cases does not correspond to the technical specifications for the industrial varieties of fluorspar and requires concentration for conversion into an industrial raw material.

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In the characteristics of the ores of our deposits, from the point of view of their fitness for concentration, both the types and physical properties of the fluorspar and also the nature of the admixture are of essential importance.

Crystalline fluorspar with a large impregnation of minerals of barren rock is easily liberated from the basic mass of the admixture, not demanding fine crushing. The simplest methods of mechanical concentration, even sorting, afford the possibility of obtaining from such ores industrial varieties of fluorspar.

Finely-impregnated ores of fluorspar, in which it is closely associated with other vein and ore minerals, are other types of ores demanding the employment of the most contemporary methods of concentration.

To the first type pertains the majority of the ores of the Solonech, Abagaytuy, Kalanguy, Taminga, Aurakhmat deposits [31,34].

To the second type pertain the ores of Takob, Khaydarkan, Amderma and Badam deposits [24].

The associated minerals in the ores of the fluorspar are, most clearly, quartz, calcite, barite, sericite, galenite, sphalerite, pyrite, cinnabar, antimonite and the products of their oxidation.

According to the nature of the admixture, it is possible to distinguish among the fluorspar ores: (1) quartz-fluorite, the concentration of which is most simple (Kalanguy, Solonech, Aurakhmat and other deposits); (2) sulfide-fluorite (Takob, Khaydarkan, and

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Anderma deposits); (3) barite or carbonate-fluorite ores, the concentration of which is most complex (Badam deposit and individual varieties of the Anderma deposit).

Methods of Concentration of Fluorspar

The methods of concentration of fluorspar depend on the nature and quantity of the minerals associated with it, on the fineness of the impregnation of admixtures and on the purpose of the fluorspar, that is, on the technical specifications.

Detrimental admixtures for the individual varieties of fluorspar are: barite, more rarely calcite, galenite, sphalerite, pyrite and all of the other sulfides, all of the other lead and zinc minerals, ferrous compounds and sulfur. In a number of cases, the method of concentration must specially have in view the bringing of these admixtures to the permissible norm of content.

The basic methods of concentration of the fluorspar ores, employed in contemporary industrial practice, are sorting and washing, jigging, concentration on tables, "dekrepitatsiya" and flotation.

In American and German industrial practice, the method of jigging is most widely employed, which processes a considerable quantity of ores in order to obtain metallurgical fluorspar [50, 52, 57]. Flotation is the most recent method and affords the possibility of obtaining a high-quality final product.

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Hand-Picking and Jigwork

With many ores of coarse composition it is possible to obtain a satisfactory product by picking out by hand the lumps of fluorspar, which are of different color and luster from the gangue.

In carrying out this operation, the fines must first be separated, as they make the classifying work difficult. In American practice, ores finer than 20 to 25 millimeters are usually separated $\frac{50}{57}$. Some plants have recently lowered this limit, bringing the size of unsorted material down to 13 millimeters $\frac{56}{7}$. Soviet hand-picking practice does not process material finer than 25 millimeters.

The efficiency of hand-picking is very low, both with respect to quality of its product and to extraction of useful mineral. Table 4 shows the results of hand-picking of one of the German deposits $\frac{51}{7}$ carried out on ore coarser than 22 millimeters.

TABLE 4

Hand-picking of fluorspar from the deposits in Saxony

Product	Yield in percent	Content in percent			Recovery of CaF_2 in percent
		CaF_2	SiO_2	Fe_2O_3	
Concentrate	34.9	96.3	3.1	0.6	40.3
Impoverished ore	65.1	76.4	21.0	2.6	59.7
Feed	100.0	83.3	14.8	1.9	100.0

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Table 5 shows the results of hand-picking of ores from the Kalangui and Solonechniy deposits under laboratory conditions. The Kalangui material picked was coarser than 75 millimeters, while that of Solonechniy, as is usual under operating conditions, was coarser than 20 to 25 millimeters.

[See next page for Table 5]

These examples are enough to characterize the possible efficiency of hand-picking. Hand-picking of the richest ores, with fluorite content of 80 to 85 percent, succeeds in extracting, in the form of type I concentrate, only 25 to 40 percent of the useful mineral. When a type II concentrate is also obtained, in addition to type I, the total recovery may be increased to 60 percent. This recovery as concentrate falls sharply as the quality of the processed ore is lowered. The low recovery by hand-picking is also, in part, due to the fact that the fines, which are not picked, generally have a higher CaF_2 content than the crude ore.

Ore classification is frequently combined with jigging. The latter process helps to assure a better picking by freeing the surface of the fluorite from clays and other impurities and giving the fluorite lumps their characteristic luster. Washing is done in washing trammels or log-washers and is combined with the separation of the fines. The friable ore met in some deposits in the United States, which is a mixture of fluorite

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TABLE 5
Hand Picking of Fluorspar

Deposit and Research In- stitute	Fineness of Ores treated, in mm	Products	Yield in percent	CaF ₂ Content in percent	CaF ₂ Extraction in percent
Kalangui (GINTSVEITMET)	75+	Concentrates	30.0	93.2	39.2
		Picking	19.2	44.3	12.1
		75-25 mm portion	26.5	72.6	37.2
		25-0 mm portion	14.3	57.0	11.5
		Feed	140.0	71.2	100.0
Solonechnoye (IMS)	20+	Concentrate I	19.4	94.9	22.4
		Concentrate II	37.9	87.8	40.3
		Halvings	24.8	67.0	20.4
		Tailings	2.6	18.4	0.8
		Siftings to 20 mm	15.3	88.8	16.1
		Feed	100.0	82.3	100.0
Solonechnoye (IMS)	25+	Concentrates	18.4	95.1	23.5
		Halvings	46.4	68.8	43.1
		Tailings	8.5	16.1	1.8
		Siftings to 25 mm	26.7	87.7	31.6
		Feed	100.0	74.3	100.0

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lumps with clay and sand, is often concentrated to a metallurgical product by a single washing in ordinary or double log-washers. The latter are used with impurer ores.

Washing is most often combined with classifying of the washed ore; lump-material on a sorting belt.

In modern concentrating mills, classification is often included in the schedules of operations. Even though it is inefficient, it still makes it possible to separate the gangue and obtain some quantity of high-content concentrate.

Jigging

The concentration of fluorspar by jigging differs in some respects from the concentration of metallic ores. The basic distinction is the yield of a concentrate in very considerable quantity, attaining 75 to 80 percent of the mill feed in some plants, and not usually falling below 50 percent.

A second feature is the appreciably lesser difference of specific gravity between fluorspar and gangue than is usually found between most metallic ores and their gangues.

In connection with the first feature, the jig must be equipped for the removal of concentrates in large amounts. Harz 5 cell jigs are usually used in American practice 50. A large side draw-off, sometimes even a double one, is sometimes used for the rapid removal of the concentrate from the

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jigger. A special type of draw-off, however, is most generally used.

The small difference between the specific gravity of fluorite (3.1 to 2.7) and that of the gangue minerals (2.6 to 2.7) requires preliminary classification of the ore. The Hancock jig operates without this preliminary classification, but turns out poor tailings and a low-quality concentrate. It is therefore employed for the initial concentration of poor fluorspar ores or for repurification of middlings and tailings to increase fluorite recovery. The final concentrates are prepared by Harz jigs after a fairly limited preliminary trommel-screening.

The ores for jiggling are first classified at the individual American mills, according to one system, into the following classes: 12 - 6.5+ millimeters; 6.5 - 3.5+ millimeters; 3.5 - 1+ millimeters, or, according to another system, into the classes: 15 - 10 millimeters; 10 - 6.5 millimeters; 6.5 - 4 millimeters; 4 - 3 millimeters; 3 - 2 millimeters.

Jiggling of material finer than 1.5 to 2 millimeters does not give satisfactory results. The ores that are most often jigged are of coarseness 13 - 2 millimeters, of course, after preliminary classification.

Concentrates containing 85 to 90 percent, and even as high as 95 percent of fluorite may be obtained by jiggling ores with coarsely disseminated quartz and calcite. Good results

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were not obtained, however, from jigging American ores with barite and sphalerite. Concentration of fluor spar ores with coarsely disseminated galenite was entirely satisfactory. It is expedient to use a separate jig to get a special lead concentrate, and the device most widely used for this purpose is the Richards pulsator $\sqrt{50}$.

Table 6 gives the results of jigging fluorspar from the Saxon deposits for high-quality concentrate $\sqrt{52}$.

TABLE 6

Jigging fluorspar from the Saxon deposits

Product	Yield in percent	Content in percent			Recovery of CaF_2 in percent
		CaF_2	SiO_2	Fe_2O_3	
Concentrate	61.7	96.3	2.8	0.9	72.7
Middlings	23.2	78.0	19.4	2.6	22.1
Tailings	15.1	28.0	68.2	3.7	5.2
Mill Feed	100.0	81.8	16.5	1.7	100.0

The practice in American concentrating mills is to obtain a metallurgical grade of fluorspar with 85 to 86 percent fluorite content by jigging, and, from ores containing galena, to obtain simultaneously a lead concentrate as well.

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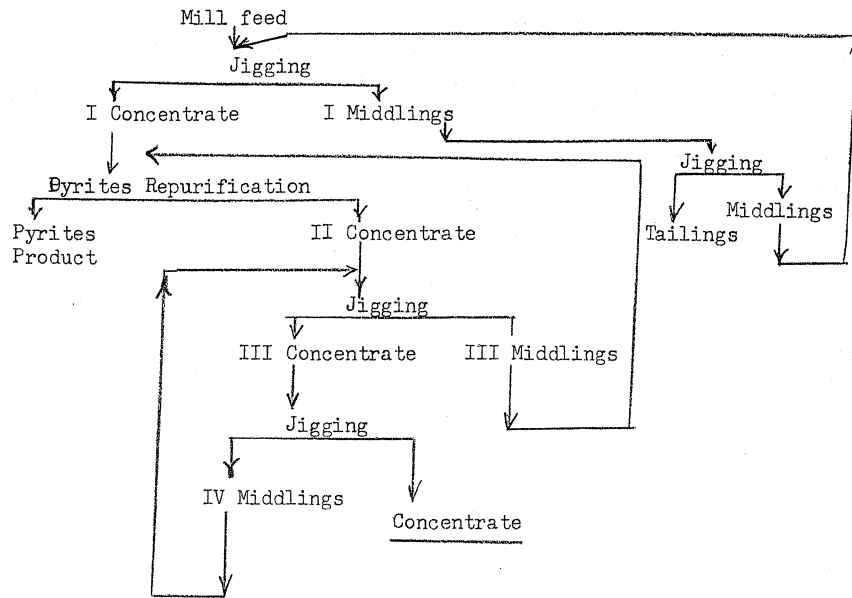
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Figure 1. Flow sheet of jigwork with American fluorspar

The possibility of concentrating the ores of our deposits by jigwork was investigated on ores from two deposits: Solonechnoye (at the Institute of Economic Mineralogy) and Amerma (by the laboratory of the Vaychag expedition) [2, 37].

The results of jigging fluorspars from the Solonechnoye deposits are given in Table 7 by separate classes of coarseness from 10 to 2 millimeters. Jigging yielded from 41 to 56 percent of concentrate with fluorite content of 91.6 to 95.1 percent; 28 to 46 percent of middlings, with fluorite content of 70.2 to 85.9 percent; and tailings with fluorite content of 43 to 61 percent, from which 5.1 to 11.1 percent of fluorite could be recovered.

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TABLE 7

Jigging of fluorspar from the Solonechnoye deposits
of coarseness 10 to 2 millimeters (IMS)

Classes in mm.	Product	Yield in percent	CaF ₂ content in percent	Recovery of CaF ₂ in percent
10 - 6.5 mm. 78.23%	Concentrate	55.2	91.60	64.5
	Middlings	30.9	70.25	27.8
	Tailings	13.9	43.50	7.7
6.5 - 4 mm. 87.07%	Concentrate	56.20	95.15	62.7
	Middlings	28.00	82.00	26.2
	Tailings	15.80	61.01	11.1
4 - 3 mm. 87.81%	Concentrate	40.9	93.9	46.4
	Middlings	46.6	81.4	45.8
	Tailings	12.5	52.7	7.8
3 - 2 mm. 86.57%	Concentrate	49.7	95.0	54.5
	Middlings	40.7	85.85	40.4
	Tailings	9.6	45.59	5.1

Table 8 gives the results of jigging a few varieties of
Anderma fluorspar by the system shown in Figure 1. This jig-

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work was aimed at removing the objectionable pyrites as well as securing a concentrate with high fluorite content, and this led to setting up the rather complicated routing shown.

TABLE 8

Concentration of Amderma fluorspars by jigwork

Product	Yield in percent	Content in percent			Recovery of CaF_2 in percent
		CaF_2	SiO_2	Fe_2O_3	
Concentrate	34.5	94.0	5.4	traces	72.2
Pyrite product	5.4	50.4	—	22.3	6.0
Tailings	60.1	16.4	20.8	traces	21.8
Mill Feed	100.0	45.0	18.3	1.2	100.0

Tabling

The concentration of fluorspars on concentrating tables is not particularly effective. Heavy minerals like galenite can be separated by this method from fluorite or from mixtures of fluorite, calcite, quartz and sphalerite. Removal of this gangue rock -- calcite, limestone or quartz -- gives a low-grade concentrate in which fluorite content is not uniform and from which recovery is low. In the US most of the existing types of concentrating tables were tried for beneficiating fluorspar, using

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modifications of the grooving, speed, slope angle, etc., but these experiments failed to give effective results [39, 50]. Concentrating mills in the US nevertheless table the fines which are obtained in large quantities from crushing ores for jigging. Before the introduction of the flotation process in fluorspar concentration, tabling was the only way recovery could be increased by treating the fines. Middlings are produced in considerable quantities by tabling. Table 9 shows data of Madel and Fischer [51] for tabling Saxon ores.

TABLE 9

Concentration of Fluorspar by Tabling

Product	Yield in percent	Content in percent			Recovery of CaF ₂ in percent
		CaF ₂	SiO ₂	Fe ₂ O ₃	
Concentrate	20.0	94.2	4.3	1.46	26.0
Concentrate	6.3	97.2	2.4	1.35	8.0
Middlings	31.2	81.2	16.5	2.26	35.0
Tailings	20.6	35.3	62.1	2.52	10.0
Slurry	21.9	71.1	26.3	2.64	21.0
Mill Feed	100.0	73.4	24.5	2.08	100.0

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The tabling qualities of Soviet ores from almost all the deposits were tested: Kalangui, Solenechnoye, Abagaitui, Aurakhmat, Khaydarkan, Takob and Badam deposits. The general conclusions which may be drawn from the series of experimental studies completely confirms the view expressed above as to the low effectiveness of concentration processes for separating non-metallic gangue minerals from fluorite [i.e. tabling and other non-flotation processes]. These conclusions may be supplemented by the further assertion that for the separation of the heavy sulphide minerals as well, which is often done by tabling in the US, flotation is a more efficient method.

Tables 10 and 11 give the results of concentrating Kalangui fluorspars on Wilfley tables, with preliminary classifications by two methods. Hydraulic classification was done on a Farenvold classifier. Fractions I and II were treated on Wilfley sand tables; fractions III and IV on Wilfley slime tables.

The 30 to 45 mesh and 48 to 65 mesh classes were treated in the same way on Wilfley sand tables, while Wilfley slime tables were used for the 65 to 120 and 120 mesh fractions. The feed contained 71 percent of fluorite. The fluorite content of the concentration yielded by screen sizing did not exceed 92.69 percent in any of the classes (Table 10). With preliminary hydraulic classification of the ore, concentrates with 9.50 to 95.1 percent fluorite content were yielding by tabling two coarser classes, but the combined recovery of fluorite in these

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classes was only 25.1 percent (Table 11). Tailings losses amounted to 22.46 to 27.22 percent. The high proportion of middlings is explained not by the presence of concretions, which were present only in insignificant amount, but by the closeness of the specific gravities of the minerals to be separated.

[See pages 469 and 470 for Tables 10 and 11]

In tabling the aurakhmat and Kalangui ores, crushing was done to 30-mesh fineness, which is sufficient for many of our ores.

The results of treatment of the finely-disseminated lead-fluorite ores of the Takob deposits may serve as a good illustration of the efficiency of tabling for separating the heavy minerals from fluorspar. The best results were obtained from 30-mesh ore, classified with a Richards classifier.

Table 12 gives the totals from one of the experiments in concentrating these Takob lead-fluorite ores.

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TABLE 10
Tabling of Kalangui Fluorspars

Mesh Classes	Yield in Percent				CaF ₂ Content in Percent				CaF ₂ Recovery in Percent		
	Class	Concentrate	Middlings	Tailings	In the class	In the concentrate	In the middlings	In the tailings	In the concentrate	In the concentrate	In the tailings
30 - 48	21.95	11.23	6.31	4.41	75.95	92.31	72.08	30.86	14.67		2.48
48 - 65	16.72	8.73	2.83	5.16	71.80	92.69	76.06	53.69	12.00		3.91
65 - 120	22.44	6.26	11.31	4.87	65.60	91.55	60.03	45.1	6.82		3.87
- 120	38.89	14.61	7.77	16.51	68.69	91.98	53.42	55.19	19.00		12.90
Mill Feed	100.0	40.83	28.22	30.95	70.64	91.80	63.0	51.4	52.49		22.46

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TABLE 11
Tabling of Kalangui Fluorspars

Fraction	Yield in Percent			CaF ₂ Content in Percent			CaF ₂ Recovery in Percent		
	Fraction	Concentrate	Middlings	Tailings	In the fraction	In the concentrate	In the middlings	In the tailings	In the concentrate
I	36.0	15.60	14.20	6.20	78.8	95.0	74.8	55.36	20.2
II	8.72	3.64	3.54	1.54	78.2	95.1	73.87	48.2	4.9
III	13.90	9.65	1.61	2.63	74.6	83.99	72.7	45.94	11.3
IV - VI	22.66	11.14	4.02	7.50	65.4	80.55	75.58	39.2	12.2
VII	18.72	-	-	18.72	38.0	-	-	38.0	-
Mill Feed	100.0	40.04	23.37	36.59	71.52	87.5	74.1	-	48.6
									27.22

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TABLE 12

Tabling Lead-Fluorite Ores of the Takoe Deposits

Products	Yield in percent	Pb Content in percent	Pb Recovery in percent
Concentrates	6.16	58.00	63.35
Middlings	53.39	2.32	20.92
Tailings	28.55	1.15	5.94
Fractions VII-X	11.90	5.55	9.79
Mill feed	100.0	6.75	100.0

The quality of the concentrate was good, and the recovery of lead in it amounted to 63.95 percent of the total. Recovery $\angle$ "recovery" as used in this translation means not metallurgical recovery but ratio of amount of a substance in any fraction to total amount in feed $\angle$ from these same ores can easily be brought up to 80 percent by flotation concentration without treating the middlings, even when the Pb content of the mill feed is lower.

Treatment of the mercury-antimony-fluorite ores of the Khaidarkan deposit, resulting in a mercury-antimony concentrate $\angle$ 1 $\angle$, led to exactly the same conclusions as to the superiority of

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of the method using only flotation. Separation of barite from fluorite in concentrating the Badam ores yields a barite product of medium purity, but a good deal of barite -- about 23 percent -- still remains in the fluorspar product.

Decrepitation

Decrepitation plays a small role in the concentration of fluorspar. This is a method based on the property of fluorite of decrepitating into a fine powder when heated to temperatures of the order of 400 to 600 degrees, which temperature has no noticeable effect on the other components of fluorspar ores, such as quartz, etc., so that they keep their granular structure. The fluorspar thus converted to powder is then separated by screening from its granular associates.

There are a number of patents containing information on this method: Germany, No 125904, 1902, Praopfe; France, No 527528, 1920, d'Allemagne; Norway, No 48166, 1926, Skappel.

By no means all fluorspars from all deposits possess the property of decrepitation. The fluorspars of some American deposits decrepitate on heating. The touting of a fluorspar concentration mill in British Columbia, using the decrepitation method, was described as early as 1929. This method, however, has failed to gain widespread acceptance.

Among Soviet fluorspar ores, those of the Aurakhmat deposits decrepitate, while those of Takob and Amdermin decrepitate partially. The Kalangui and Abagaitui do not.

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Table 13 shows the results obtained by decrepitation of separate fineness fractions of Aurakhmat fluorspars.

See next page for Table 13

These data show that a finished concentrate can be obtained by decrepitation from some ores. The low recovery of fluorite in the concentrate, even from the medium coarse fractions that decrepitate best, ~~is~~ is an essential defect of this method.

Material larger than 50 millimeters decrepitates very poorly. On the other hand, the fines, especially the fractions finer than 20 mesh, also give very unsatisfactory recoveries. The medium-coarse fractions from 50 millimeters to 20 mesh give a recovery of 45.6 to 53.4 percent in the final concentrate with about 95 percent fluorite content. The tailings obtained are very rich in fluorite and cannot be considered waste. But the question still remains how to treat the classes finer than 20 mesh, which make up about 26 percent of the total yield from milling Aurakhmat ores to 50 millimeters and contain about 27 percent of the fluorite in the crude ore.

The unpopularity of the decrepitation method of concentrating fluorspar ore may be explained by these reasons, in spite of the fact that tests in some cases do occasionally show high indices.

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TABLE 13

Decrepiation of Aurakmat Fluorspar

Classes	Yield of Class in percent of feed	CaF ₂ content in percent	Size of Pro- ducts in mesh	Yield in percent	CaF ₂ con- tent in percent	Recovery of CaF ₂ in percent
-50+18.9 mm	9.46	40.77	+5	79.8	27.12	53.05
			-5+150	19.52	95.1	45.6
			-150	0.68	81.51	1.36
-18.9+6.7 mm	19.06	58.22	+8 mesh	65.97	39.5	44.64
			-8+150 "	32.66	94.9	53.34
			-150 "	1.37	86.06	2.02
-3+8 mesh	19.67	76.0	+10 mesh	31.68	36.65	15.90
			-10+20 "	21.08	85.26	24.55
			-20 "	47.24	92.21	59.55
-8+20 "	25.78	80.07	- 8+20	39.6	57.8	28.6
			-20+48	45.3	95.36	53.44
			-48	15.1	92.62	17.45
-20+35 "	8.65	90.62	+35	62.9	87.1	60.45
			-35	37.1	96.68	39.55

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TABLE 13 (Continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
-35-48 mesh	5.19	76.38	+48 mesh	54.49	73.5	52.5
-48-120 "	5.58	66.20	-48 "	45.51	86.66	47.5
-120 "	6.31	56.78				
					was not decrepitated	

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Flotation is the most perfected method of concentrating fluorspar ore. It makes it possible to obtain fluorspar with exceptionally high fluorite content, running up to 98 percent and higher. But it yields the concentrate in powder form, the fine grain of which makes it difficult to use in some branches of industry. This is a partial disadvantage of this method. The first reports of fluorspar flotation date back to 1925. As with other ores, flotation makes it possible to utilize fluorspar that it would be almost impossible to concentrate in any other way.

The first flotation mills for concentrating fluorspar were started up in 1929 in the US, and in 1931 in Germany [52]. This method of concentrating fluorspar is thus the newest method of all.

Coghill and Greeman used the following mixture of agents in testing the amenability of fluorspar to flotation [44]: oleic acid, 0.450 kilograms per ton; sodium oleate, 0.045 kilogram per ton; sodium silicate, 0.090 kilogram per ton; sodium carbonate, 0.090 kilogram per ton; pine oil, 0.090 kilogram per ton distilled pine oil, 0.045 kilogram per ton.

The concentration of ore with 67.9 percent of fluorite, crushed down to 100 mesh, yielded a concentrate with 98.2 percent of CaF_2 . Table 14 shows the results of this experiment.

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TABLE 14

Flotation of Fluorspar

Products	Yield in percent	Content in percent		Recovery of CaF_2 in percent
		CaF_2	SiO_2	
Concentrate	56.0	98.2	0.6	81.1
Middlings	17.8	61.7	33.2	16.1
Tailings	26.2	7.3	82.7	2.8
Feed	100.0	67.9	27.9	100.0

Madel and Fisher studied the concentration of fluorspar from one of the Saxony deposits, containing 84.7 percent fluorite, and obtained a concentrate with 99.0 percent CaF_2 content after two flotations [51]. Table 15 shows the results of this laboratory experiment.

The first investigations on the flotation of our fluorspar ores were conducted in the Institute of Applied Mineralogy and Non-Ferrous Metallurgy in 1928, i.e. at almost the same time as the inception of research abroad.

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TABLE 15

Flotation of Fluorspar

Operation	Products	Yield in percent	Content in percent			Recovery of CaF_2 in percent
			CaF_2	SiO_2	Fe_2O_3	
Rougher flotation	Feed	100.0	84.7	13.7	1.6	100.0
	Rougher concentrate	85.3	91.8	6.9	1.3	92.4
	Middlings	8.3	58.8	32.4	2.8	5.8
	Tailings	6.4	24.3	72.5	3.2	1.8
Cleaner flotation	Concentrate	64.5	99.0	0.3	0.7	75.4
	Middlings	20.8	69.1	27.9	3.0	17.0

These investigations were subsequently continued in the same institute (now the Institute of Economic Mineralogy) in the Institute of Non-Ferrous Metals and MEKHAHOBR.

The absence of any detailed information on the flotation of fluorspar in the foreign literature, which absence was probably connected with the commercial interests of firms, led to our conducting our own completely independent research on this subject. The detailed study of fluorspar flotation led to interesting conclusions which may also be of significance for other economic minerals such as phosphorite and barite, etc. with properties similar to those of fluorspar.

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The flotation of pure fluorite was studied in the Institute of Economic Mineralogy. In the course of this study the influence of hydrogen-ion concentration in the pulp on the flotability of pure fluorite was studied. In these projects the flotation of fluorite in the presence of electrolytes was studied, and a number of activators and depressants in the flotation, possessing activating powers in this respect, were found. The flotation characteristics of a number of organic substances proved to be entirely different, when studied on fluorite, than what they had generally been assumed to be. Many organic substances considered inhibitors and even in some cases flotation poisons, turned out to be activators and collectors with respect to fluorite flotation. Our views of flotation characteristics of organic compounds require very serious correction in connection with this. The details of these projects are discussed below in the chapter "Flotation of Fluorite in the Presence of Inorganic and Organic Regulators".

Oleic acid and its sodium salt 22 are in fact the only important collectors used in industrial practice for the flotation of fluorspar. Substantial disadvantages in the use of oleic acid are the lack of uniform quality in the technical product used in industry, its sensitivity to the temperature of the pulp, its very considerable sensitivity to the hydrogen-ion concentration in the pulp and its high cost, together with the fact that it is in short supply in our economy. The Institute

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of Economic Mineralogy has therefore studied a number of other flotation reagents for fluorspar besides oleic acid. They are oxidation products of paraffin [23], oxidized petroleum oils, and peat resin.

The compound reagent IMS-211, proposed by the Institute, gave good results in fluorspar flotation. This reagent gave higher flotation indices than oleic acid when tested on Solonechnoye, Kalangui and Takob ores, and is considerably cheaper. The Gal'perin No 2 and No 3 compound reagents, prepared by the Vaychag Laboratory of the GLAVSEVMORPUT', gave good results in the flotation of Anderma fluorspar [2, 3]. Detailed data on flotation agents are presented in the chapter "Flotation Agents for Fluorspar".

The consumption of a collector in fluorspar flotation ranged 0.3 kilograms for the cleanest ores and most active of the collectors to 1.5 kilograms for dirty ores.

The collectors used in fluorspar flotation also possess froth-raising properties. In spite of this, special frothing agents are also used in a number of cases to improve the quality of the froth and increase the efficiency of the flotation process. Pine oil is usually employed for this purpose. Greslic acid also gave good results in many instances.

In most cases fluorspar flotation is done in an alkaline medium. Sodium carbonate or hydroxide is therefore added to the

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pulp to alkalize it. Sodium hydroxide gave the best results with Soviet ores. Lime is not used for this purpose, since it reacts with the carboxylic acids to form calcium soaps of low solubility.

Sodium silicate is one of the commonest flotation agents for fluorspar. It acts as an depressant for quartz, and used in small amounts it activates fluorite flotation, disperses the argillaceous substances in the ore-pulp, clears the surfaces of the mineral granules, and improves the qualities of the froth. A typical example of the influence of sodium silicate in the flotation of fluorspar ores is given in Table 16 [25].

[See next page for Table 16]

The normal pulp consistency in flotation of fluorspar ores corresponds to a solids to liquid ratio of 1:4. Increase in pulp consistency unfavorably effects the quality of the concentrate and is especially marked in its effect on the cleaner flotation of fluorspar.

Pulp temperature is very important in fluorspar flotation. In flotation with carboxylic acids and other collectors of low solubility in water, that have low freezing points, all flotation indices are improved by increasing temperatures.

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TABLE 16

Effect of Sodium Silicate on the Flotation of
Solonechnoye Fluorspars with Oleic Acid (IMS)

Use of sodium silicate in grams per ton	Products	Yield in percent	CaF ₂ content in percent	CaF ₂ recovery in percent
0	Concentrate	76.9	91.91	86.4
	Tailings	23.1	48.2	13.6
150	Concentrate	77.0	94.01	88.6
	Tailings	23.0	40.35	11.4
200	Concentrate	80.6	94.62	93.3
	Tailings	19.4	28.30	6.7
300	Concentrate	79.4	94.15	91.3
	Tailings	20.6	34.62	8.7
700	Concentrate	77.6	95.15	90.3
	Tailings	22.4	35.31	9.7
	Mill feed	100.0	81.74	100.0

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In flotation with oleic acid and other acids, there is a marked improvement in the efficiency of the flotation process when pulp temperature is increased to 23 to 24 degrees. Further increases have little effect. Reduction of the temperature below 12 to 14 degrees leads to a sharp drop in the recovery of useful mineral in the concentrate and a very considerably though not so marked deterioration in the quality of the concentrate.

Figure 2 shows the change in yield of concentrate from Solonechnoye fluorspars at various pulp-temperatures, in flotation with oleic acid. Table 17 gives more detailed data on the effect of pulp-temperature on flotation of Takob fluorspar with IMS -211 agent.

Yield in percent

Temperature in degrees Centigrade

Figure 2. Effect of pulp temperature on the flotation of Solonechnoye fluospars with oleic acid

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TABLE 17

Effect of Pulp Temperature on the Flotation of
Takob Fluorspars (IMS)

Pulp temperature in degrees Centigrade	Products	Yield in percent	CaF ₂ content in percent	CaF ₂ recovery in percent
3	Concentrate	19.6	78.7	26.1
	Tailings	80.4	54.5	73.9
8	Concentrate	49.6	85.3	71.6
	Tailings	50.4	33.5	28.4
14	Concentrate	63.3	83.8	90.6
	Tailings	36.7	13.9	9.6
25	Concentrate	69.6	79.7	93.7
	Tailings	30.4	12.2	6.3
	Mill feed	100.0	59.2	100.0

The properties of the water have a very great importance in fluorspar flotation. Increasing its hardness, its content of dissolved salts, acts unfavorably on the flotation process. Fluctuations in the content of dissolved salts that upset the

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established flotation procedure are especially harmful. When sodium hydroxide is added to the pulp as is usual in fluorspar flotation, a considerable part of it is used up in eliminating the temporary hardness of the water, while the remainder goes towards increasing the alkalinity of the medium. If the temporary hardness changes, the amount of sodium hydroxide used up in overcoming it also changes, resulting in violent fluctuations in the pH of the pulp. Thus even small changes in the temporary hardness of the water are sharply reflected in the concentration of hydrogen-ions and accordingly in the progress of the flotation process.

The separation of the fluorspar from the accompanying minerals is not uniform for all the frequently encountered natural associations.

The separation of fluorspar from quartz by flotation proceeds in a highly satisfactory manner. Sodium silicate in amounts from 200 to 1,000 grams per ton is usually employed as an inhibitor for quartz. Concentrates with CaF_2 content ranging from 95 to 97 or 98 percent, with high recovery, fluctuating between 85 and 95 percent, can be obtained by flotation of quartz-fluorite ores. Table 18 gives the results of flotation for a number of these ores from Soviet deposits, most of which require crushing to 100-mesh fineness.

The separation of fluorspar from the sulfides -- galenite, sphalerite, cinnabar and stibnite, and their oxidation products --

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is just as easy. Completely satisfactory results are obtained from flotation of non-ferrous ores, both in the USSR and the US. Flotation is the only method used in the US for separating sphalerite and fluorspar. Flotation of the lead-fluorite ores of the Takob deposit yields high-grade concentrates, lead with 60 percent Pb content, fluorspar with 96 to 97 percent CaF_2 . Flotation of the zinc-fluorite Aderma ore similarly yields finished zinc and fluorite concentrates [2, 3].

Table 19 gives flotation results for a few sulfide-fluorite ores.

[See Tables 18 and 19 on pages 486 and 487]

In many cases the sulfides in our ores are oxidized to a considerable extent, and sometimes even completely replaced by oxides. The usual agents are used in the flotation of sulfides and their oxides: xanthates, pine oil, sodium sulfite, sodium silicate and copper sulfate. The flotation of the fluorspar is done after the separation of the sulfides, and the usual agents for fluorspar flotation are employed.

The non-ferrous fluorspar ores of the USSR require finer crushing than the quartz-fluorite ores: 80 to 94 percent to pass a 200-mesh sieve, for the Aderma ores, and 88 percent to pass a 200-mesh sieve for the Takob ores.

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TABLE 18
Flotation of Quartz-Fluorite Ores

Deposit, by whom in- vestigated, and year of investigation	CaF ₂ content in mill feed in percent	Products	Yield in percent	CaF ₂ content in percent	CaF ₂ recovery in percent
Aurakhmat (IMS, 1932)	53.06	Concentrate	43.7	96.25	78.6
		Middlings	13.8	60.0	15.6
		Tailings	42.5	7.18	5.8
Aurakhmat (GINTSVETMET, 1933)	69.7	Concentrate	68.1	96.12	94.7
		Tailings	31.9	11.48	5.3
Solonechnoye (IMS, 1934)	79.62	Concentrate	71.2	97.28	87.7
		Middlings	—	—	—
		Tailings	28.8	33.0	12.3
Kalangui (IMS, 1934)	65.63	Concentrate	56.4	96.82	81.4
		Middlings	12.2	52.3	9.4
		Tailings	31.4	18.83	9.2
Solonechnoye (IMS, 1935)		Concentrate	67.5	97.26	90.0
		Middlings	7.1	47.10	4.24
		Tailings	25.4	16.37	5.76

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TABLE 19
Flotation of Sulfide-Fluorite Ores

Deposit and by whom investigated	Products	Yield in percent	Content in Percent				Recovery in Percent			
			CaF ₂	Pb	Zn		CaF ₂	Pb	Zn	
Takob (IMS)	Mill Feed	100.0	44.3	2.4	—		100.0	100.0	—	—
	Lead Concentrate	3.7	—	52.0	—		2.5	80.0	—	—
	Fluorspar Concen- trate	40.6	97.3	—	—		90.2	—	—	—
	Tailings	55.7	5.8	—	—		7.3	20.0	—	—
Anderma (Vaychag Laboratory of GLAVSEVMORPUT)	Mill Feed	100.0	47.5	—	1.76		100.0	—	100.0	
	Lead Concentrate	3.0	4.6	—	49.5		0.3	—	87.9	
	Fluorspar Concen- trate	45.0	98.6	—	—		92.4	—	12.1	
	Tailings	52.0	6.5	—	—		7.3	—	12.1	

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The separation of fluorspar from barite by flotation encounters considerable difficulties. There is no precise information available on the concentration of these ores abroad. In experiments on the amenability to concentration of the Badam fluorite-barite ores, mechanical ore-dressing gave unsatisfactory results. Eygeles of the IMS has worked out a flotation method for separating mixtures of pure fluorite, barite and quartz minerals which yields a pure fluorite and a pure barite concentrate with a high recovery. Table 20 shows the results of one of these experiments in differential flotation of a mixture of fluorite, barite and quartz.

TABLE 20

Differential Flotation of a Mixture of
Fluorite, Barite and Quartz

Products	Yield in percent	Content in percent			Recovery in percent		
		CaF ₂	BaSO ₄	SiO ₂	CaF ₂	BaSO ₄	SiO ₂
Concentrate I	40.7	98.1	0.96	0.77	99.8	1.0	1.6
Concentrate II	39.0	0.3	93.6	4.4	0.1	91.2	8.6
Tailings	20.2	0.2	15.4	88.9	0.1	7.8	89.8

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A number of inorganic and organic depressant agents are used for the selective depression of barite: compounds of chromium and manganese, carbohydrates and tanning agents.

The separation of fluorspar from calcite by flotation also encounters considerable difficulties. There are some indications of satisfactory results in separating calcite from fluorite on a laboratory scale by treating a mixture of their powders with a strong solution of copper sulphate and amyl xanthate. Williams and Greeman (American patent No 1785935 of 1930) achieved satisfactory results in flotation of fluorspar with a high calcite content by desliming in the presence of a number of agents (copper, sulphate, sodium sulphite). Satisfactory results were achieved in the flotation of fluorspar with a 19.1 percent CaCO_3 content in the laboratory of the Amderma mine of the Central Administration of the Northern Maritime Route (by Gal'perin); the CaCO_3 content of the concentrate was about one percent $\frac{1}{3}$. The Gal'perin agent No 3 was used in the flotation. Eygeles (in the IMS) separated a mixture of fluorite and calcite, using selectively acting inorganic and organic depressing agents for calcite in addition to the usual collector, oleic acid.

More detailed data on the differential flotation of fluorite, barite and calcite may be found in the chapter "Differential flotation of fluorite".

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The flow-sheets of concentration mills for fluorspar represent a combination of the methods of concentration enumerated above, selected in accordance with the properties and composition of the ore, as well as whether the mill is intended to turn out lump and gravel spar (metallurgical grade) or the high-quality acid-grade fluorspar.

THE FLOTATION OF FLUORITE IN THE PRESENCE OF
INORGANIC AND ORGANIC REGULATORS

Very little study has been devoted to the flotation of non-metallic minerals. A certain amount of work has been done on the amenability to flotation of the most widely distributed minerals of the so-called waste rock: quartz and calcite. Very little attention has been paid in theoretical work to other non-metallic minerals, to the concentration of which flotation has been recently applied on an ever widening scale; their floatability has been studied incidentally to the development of concentration methods for the individual ores. The study of the floatability of pure minerals, however, is of very considerable interest for the solution of the most complex problems of differential flotation. Thus, for instance, the flotation of the pure metallic minerals, galenite, sphalerite, chalcopyrite, etc., has been studied in great detail [47] in the work of a number of investigators, and this made it possible to establish a number of general relations governing the flotation of these minerals, in spite of the individual peculiarities of ores. The study of non-

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metallic mineral flotation is only beginning. The amenability of pure fluorite to flotation has been studied by the Institute of Economic Mineralogy.

The flotation of non-metallic polar minerals is performed by the use of carboxylic acids. According to our present ideas, the mineral granules acquire the property of floating, i.e. of attaching themselves to air bubbles and floating up to the top, thus forming a mineralized froth, by virtue of changes in their surface properties under the influence of the collector 7, 15, 17, 18⁷.

There is still no complete theory of flotation at the present time -- no theory embracing all sides of this most complicated subject and assuring the possibility of theoretical solution of a number of concrete problems. In studying the separate elements of the process, the greatest attention is paid to the changes on the surfaces of the mineral granules which give them the property of floating, to the formation of froth that possesses the required properties, and to the creation of the conditions which make the elementary act of flotation possible -- the attachment of the mineral granule to the air bubble.

According to the theory developed by Langmuir, changes in the surface properties of minerals are based on a definite orientation of the adsorbed molecules of a surface-active collaborator.

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The stability of the film formed is strengthened by chemical fixation in cases where the polar portion of the collector unites chemically with the cation of the crystal lattice of the mineral to form a compound of low solubility [7].

The work of Gel'd and his associates [6] established the considerable influence of the electrolytes dissolved in the aqueous phase of the mineral suspension, on the adsorption of surface-active organic substances upon the faces of the crystals. The electrolytes dissolved in the pulp act even more vigorously owing to their immediate adsorption upon the faces of the crystals. The work of Eygeles on fluorite and barite has confirmed the considerable influence of the electrolytes used in the flotation of these minerals on their surface properties, on the aggregational condition of their suspensions, and on the degree to which they are flocculated by a collector.

Besides the mineral granules, the air bubbles forming the froth are another very important element in flotation. The theory of flotation, that is, of the tri-phase froth, has been most inadequately developed. Inasmuch as solid particles also participate in the structure of the foam, along with the bubbles in their watery envelopes, it is absolutely indispensable to consider not only the interaction of the bubbles with the particles, in any study of foam properties, but also the interaction between the particles. Talmud [18] particularly points this out. The

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active process of flotation must obviously be connected with the conditions under which the particles adhere to each other, forming armored bubbles and resulting in multi-stratum flotation.

P. A. Rebinder [17] furnishes the most complete basis, in physical chemistry, for the fundamental element of the process of flotation, the adherence of the solid particle to the air bubble. His theory is founded on the thesis that the nature of the flotational force is identical with that of the wetting force. Z. V. Volkova, on the other hand, explains flotation as due to the mechanism of coagulation [4].

Nilsson [54] mentions the importance of still another factor, the speed of adhesion of the bubble to the mineral particles, which may vary within wide limits according to the previous processing of the particles.

The inadequate development of the theory of flotation makes it necessary to engage in detailed experimentation to ascertain the optimum flotation conditions and to select the flotation agents -- depressors and activators -- best suited to assure the selectivity of the process in treating the mineral associations encountered in nature.

The flotation practice of recent years has shown conclusively that success in the flotation of ores of different types depends almost entirely on introducing the right flotation regulators -- depressors and activators -- into the pulp.

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investigation. By using so coarse a grain the effect of slimes, which complicate flotation study, could be avoided.

The entire experimental work of the investigation was done with a laboratory flotation machine made of celluloid, of minerals separation type and capacity 250 cubic centimeters [text says 250 square centimeters] Oleic acid and a mixture of carboxylic acids from the oxidation products of paraffin wax were used as collectors. Pine oil was the frothing agent. The oleic acid was introduced in alcoholic solution, and the carboxylic acids in benzine. The water-soluble agents were used in aqueous solutions of various concentrations, depending on their solubility, and most often in one percent solution. H-ion concentration -- the pH of the pulp -- was determined in all the flotation experiments, calorimetrically for acid and neutral pulps, potentiometrically for the alkaline pulps.

The study of fluorite flotation with oleic acid and a mixture of carboxylic acids, at varying pulp pH, showed a considerable dependence of concentrate yield on pulp alkalinity.

Figure 3 shows the results of a series of experiments with fluorite flotation, after addition of hydrochloric acid or caustic soda to the pulp. For both collectors the pH γ curves are of closely related character.

There are stable zones, with both oleic acid and the carboxylic acid mixture, in which fluctuations in the pH of the

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pulp have little effect on the extraction of fluorite. But in the unstable zones, the latter fluctuates sharply with even slight changes in the pH. With constant quantity of collector, the yield of concentrate rises with increasing alkalinity of the pulp. Both curves have points of inflection corresponding to maximum yield of fluorite. Further increase of pH reduces it. The dependence of fluorite yield on the pH of the pulp is less marked with the carboxylic acids than with oleic acid. The great stability of the process in flotation with a mixture of carboxylic acids has been fully confirmed with a number of fluorspar ores.

Figure 3. Flotation of fluorite with varying pH of the pulp
1 - oleic acid 2 - carboxylic acids

A considerable amount of experimental work was done on the selection of regulators for fluorite flotation, both depressors and activators. The amount of attention hitherto devoted to studying the mechanism of the depressant action has been completely inadequate. Various hypotheses have been formulated by different research workers to account for the phenomena of depression. The applicability of some of these to soap flotation was tested during the study of the effect of a large number of compounds on the flotation of fluorite, barite and calcite. Among the depressors certain compounds were found which, according to the views of Goden and Taggart, form compounds with the cations of the crystal

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lattice which are less soluble than those formed with those cations by the anions of the collector. The depressant action of a number of organic and inorganic colloids may be explained by their adsorption upon the faces of the mineral granules and the formation of hydrated films.

A group of salts with the same crystal structure as the mineral subjected to depression was also found to exert a depressant action. Thus KClO_4 , K_2CrO_4 , and CaSO_4 , all of which have a crystal structure very similar to that of barite, act as depressants for it. The depressant action of calcium sulphate on barite is characteristic of it, while other calcium salts, for instance the chloride, have no effect whatsoever on barite flotation. The inadequacy of purely chemical ideas as to the reactions between an electrolyte and a crystal surface is also emphasized by the entirely different flotational effects shown by oxalic acid and sodium oxalate.

The studies of the floatability of fluorite in the presence of inorganic electrolytes at the Institute of Economic Mineralogy included:

- (1) Salt electrolytes having cations or anions in common with the mineral;
- (2) Inorganic compounds, mostly depressants and activators used in practice, and salt electrolytes capable of forming Ca^{++} compounds of varying solubility in the given solution by interaction between their anions and the cations of the crystal lattice of the mineral under study.

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Two salt-electrolyte groups of these compounds were selected and studied; salts of trivalent and bivalent metals, and alkali metals with various anions.

A number of theoretical investigations have regarded salts with ions common to the mineral in question as actively functioning as flotation regulators for polar minerals. Some papers express the view that such salts act as depressants. This position has been experimentally confirmed by D. L. Talmud and N. M. Lubman [19] in work on the flotation of silver iodide, calcium carbonate, and barium sulphate, in the presence of considerable amounts of silver nitrate, potassium iodide, calcium chloride, sodium carbonate, barium chloride and sodium sulphate. Recent work of N. A. Gel'd on the adsorption of the ions of a collector by mineral surfaces connects the action of salts with common ions on minerals with selective adsorption of the electrolyte cations and anions, which strengthens or sharply reduces the adsorption of the collector. His idea is that when ions are adsorbed, a salt with a common cation should activate the mineral, while one with a common anion should depress it.

The data obtained in the Institute of Economic Mineralogy on flotation of fluorite in the presence of the common ions Ca and F⁻ are shown in Figure 4.

Yield in percent
 _____ Grams per ton

Figure 4. Effect of common ions on the flotation of fluorite

1 - CaCl_2 2 - NaF

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It may be seen from this chart that calcium chloride exerts no appreciable effect on fluorite flotation. Sodium fluoride markedly increases the fluorite yield, and in quantities of 1,000 grams per ton and over it becomes an activator for fluorite. These experimental data do not confirm the applicability of the working hypotheses of Talmud and Gel'd to fluorite flotation with oleic acid.

The next group of electrolytes to be studied consisted of the salts of trivalent and bivalent metals, and of silver. The salts of trivalent metals are well known to be energetic depressants for a number of minerals, such as, for instance, calcite and magnesite. The salts of many bivalent metals act in the same way, but less energetically. Silver salts usually have the same effect on flotation as salts of bivalent metals.

In the work at the Institute of Economic Mineralogy, the effects of chromium and aluminum nitrates, iron, lead, zinc, copper and silver oxides, iron and copper sulphates, and iron and magnesium oxychlorides on fluorite flotation were studied. Figure 5 and 6 show the results of the series of experiments.

The experimental data graphically shown by Figure 5 indicate that the effect of ions of salts of trivalent metals on fluorite flotation is not uniform. Ferric salts commence to act as energetic depressants of fluorite at concentrations of 250 grams per ton. Aluminum nitrate acts as a depressant only at increased concentrations (about 1000 grams per ton).

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At lower concentrations than this, it activates fluorite flotation. Chromium nitrate acts as a weak activator. The difference in the magnitude of the effect of ferric nitrate and ferric chloride is explained by the difference between their molecular concentrations, and thus also between their flotational action, at the same concentration in grams.

Yield in percent

 Concentration grams per ton

Figure 5. Effect of salts of trivalent metals on fluorite flotation

Yield in percent

 Concentration grams per ton

Figure 6. Effect of salts of bivalent metals on fluorite flotation

Yield in percent

 Concentration grams per ton

Figure 7. Effect of alkali salts with various anions on fluorite flotation

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The character of the action by salts of bivalent metals on fluorite flotation may be judged by Figure 6. Most of these salts studied depress fluorite. Hydrated ferric sulphate (iron copperas) is a strong depressant, actively functioning as such at concentrations as low as 250 grams per ton. Copper sulphate and nitrate energetically suppress the flotation of fluorite. Lead nitrate and magnesium chloride show no noticeable depressant effect. Finally, silver nitrate behaves like most other salts of the heavy metals in depressing fluorite flotation.

As a whole the study of the action of salts of trivalent and bivalent metals led to the conclusion that the ferric and ferrous salts of the strong acids, copper and silver salts are active depressants of fluorite. The weakly activating effect of chromium nitrate and of low concentrations of aluminum nitrate on fluorite is interesting.

To study the effect of various anions on fluorite flotation, the influence of introducing dissolved sodium and potassium salts into the pulp was examined. In the experimental work of the Institute of Economic Mineralogy, the action of sodium silicate, phosphate, pyrophosphate, carbonate, sulphate, chloride and iodide, and of potassium cyanide, chloride, chromate, bichromate, permanganate and ferrocyanide on fluorite flotation was studied. Figure 7 shows the results of fluorite flotation with oleic acid in the presence of these salts.

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The alkali salts with various anions exert varying influence on fluorite flotation. Sodium silicate (water glass) in amounts of 500 grams per ton has a mild activating effect. In concentrations of 750 to 1000 grams per ton, however, it completely interrupts flotation in the presence of 50 grams per ton of oleic acid. The depressant action of sodium pyrophosphate is considerably weaker. Sodium carbonate, phosphate and sulphate, and potassium cyanide, activate flotation of fluorite; sodium chloride, chlorate and iodide have no appreciable effect in amounts ranging from 50 to 1000 grams per ton. Potassium chromate, bichromate and permanganate are strong activators for fluorite, displaying considerable activity at levels as low as 50 to 250 grams per ton. Potassium ferrocyanide displays a very weak activating effect.

Oxalic acid had a very interesting effect on fluorite flotation. As is well known, oxalic acid yields the difficulty soluble calcium oxalate with calcium salts. The insolubility of calcium oxalate led one to expect that oxalic acid would act as a depressant for fluorite.

The experimental data, as may be seen from table 21, confirm this expected depressant action.

The influence of oxalic acid in more acid, and in neutral, media, was also studied.

The pulp was acidified with hydrochloric acid, and neutralized with caustic soda.

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TABLE 21

Flotation of Fluorite in the Presence of Oxalic Acid

Concentration of oxalic acid in grams per ton	pH of the pulp	Yield in percent
0	5.8	21.5
50	5.8	33.7
100	5.9	13.3
250	5.7	0.45
500	5.8	0.2

TABLE 22

Flotation of Fluorite in the Presence of Oxalic Acid
(with varying pH)

Concentration of oxalic acid in grams per ton	pH of the pulp	Yield in percent
500	3.4	0.0
500	5.0	0.0
500	5.8	0.15
500	6.0	57.4

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Oxalic acid maintains its depressant action in an acid medium, but fails to do so in a neutral medium.

Addition of caustic soda resulted in good flotation even with increased concentration of oxalic acid.

At a pH of 6.7, flotation could be suppressed only by using 4500 grams of oxalic acid per ton of fluorite.

Sodium oxalate showed no depressant action upon fluorite.

The first experiment was conducted with a charge of 1000 grams of sodium oxalate per ton and a small amount of caustic soda to obtain a pH over 8. Under these conditions the flotation of fluorite proceeded very energetically. Subsequent addition of sodium oxalate in separate stages, up to 1000 grams per ton, did not depress flotation. The next experiment was conducted without use of caustic soda, at a pulp pH of 6.5.

Flotation of fluorite proceeded rather energetically at a sodium oxalate level of 500 grams per ton, and its subsequent increase to 4500 grams per ton had no appreciable depressant effect.

To intensify the interaction between the sodium oxalate and the cations of the crystal lattice, heated pulp was used in one experiment, during which, at a sodium oxalate level of 5000 grams per ton, flotation proceeded very energetically and resulted in practically total recovery of the fluorite. A charge of 10,000 grams of sodium oxalate per ton likewise did not suppress flotation, and the yield of concentrate was 94.3 percent using 125 grams of oleic acid per ton.

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The conclusion may thus be drawn that sodium oxalate behaves differently from oxalic acid, for while the latter, even at 250 grams, completely depresses fluorite, and is thus a most powerful depressant, the former, even in concentrations exceptional in flotation practice, has almost no effect on fluorite flotation.

The work of the Institute of Economic Mineralogy has given a considerable amount of attention to the effects on fluorite flotation manifested by a group of organic substances, most of which are currently classed, by present ideas, as depressants. These organic compounds are all the more interesting by reason of the fact that in spite of their strong influence of the process of flotation, they have never been systematically studied by anyone.

In his experimental work at the IMS, Eygeles studied the influence exerted on fluorite flotation by the proteins -- albumin, peptone, gelatin and casein; by the carbohydrates -- starch, dextrin and glucose; and by the tanning substances -- tannin and cellulose sulfite extract.

Simultaneously a number of aromatic para-compounds were studied that had been mentioned as depressants in the papers of a few research workers. Detailed study of these organic compounds allowed the singling out of a few substances among them whose behavior towards fluorite flotation contradicted the generally accepted views. Among them activators

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of fluorite were found, and also weak collectors. These experiments considerably broadened the arsenal of agents and made it possible to control the process of flotation of fluorite, which is particularly important in complex situations of differential flotation.

The proteins -- albumin, gelatin, casein and peptone -- are typical lyophile colloids, which have the property of protecting lyophobic colloids from coagulation. The current views regards the protective action of the lyophile colloids as being due to their adsorption of disperse particles, to the surfaces of which they pass on their own properties.

If this view is applied to mineral suspensions, it would be natural to expect the formation of a protective, strongly hydrophilic film to result from the adsorption of these colloids upon the surfaces of the mineral particles. The theory and practice of flotation see in such a hydrophilization the cause of the suppression of the flotational process ascribed to these proteins.

The results of the experiments on the flotation of fluorite in the presence of proteins are graphically represented in Figures 8 and 9, and show that there are very marked differences between the action of the various proteins on the flotation of fluorite. Albumin in concentrations of 1,000 grams per ton completely suppresses flotation. In low concentrations gelatin acts as an activator, but in considerable concentrations (1,000

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grams per ton) it depresses fluorite flotation. Peptone is a strong activator towards the flotation of fluorite with oleic acid. Casein does not depress, but on the contrary is a strong activator in low concentration.

When the medium is subsequently acidified or alkalinized, the changes in the flotational behavior of the various proteins are not uniform. Flotation of fluorite in the presence of albumin or gelatin is suppressed in an acid medium, and is likewise considerably reduced in an alkaline medium. The behavior of casein and peptone is entirely different, for in their presence the flotation of fluorite in these media proceeds. Casein stands out with particular sharpness in this connection, for it increases the flotation of fluorite not only in an alkaline medium, but even when the pulp is acidified.

After casein alone had been introduced into the pulp, a very perceptible flotability of fluorite was noted after mechanical agitation for three minutes, in the absence of both oleic acid (as collector) and pine oil (as frothing agent).

Supplementary experiments were then staged in fluorite flotation using casein alone.

The results showed casein to behave towards fluorite as a collector.

The activating influence of casein on fluorite flotation with oleic acid is apparently to be explained by the additional collection-inducing and froth-forming properties of casein.

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Figure 8. Flotation of fluorite in the presence of proteins.

Side axis -- γ %
 Bottom axis -- Concentration in grams per ton

1 -- albumin 2 -- gelatin 3 -- peptone 4 -- casein

Figure 9. Flotation of fluorite in the presence of proteins at varying pH.

Top -- Yield in % Bottom -- pH

1 -- albumin 2 -- gelatin 3 -- casein

The proteins develop a very marked frothing action in the course of flotation. In some cases abundance, particular elasticity, and persistence of the froth is observed. The activating powers of some proteins may possibly be attributed, in greater or lesser degree, to these characteristics.

Solutions of starch, dextrin and glucose were selected for the study of the influence of carbohydrates on fluorite flotation. Starch and dextrin are both negatively charged lyophile colloids, with protective gold numbers of 25.0 for starch and 4.0 for dextrin.

Figure 10 shows the results of fluorite flotation in a neutral medium.

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Figure 11 shows the results of the experiments in fluorite flotation in the presence of carbohydrates, with varying pH of the medium.

Starch is observed to act in a dual manner in fluorite flotation. In low concentrations it activates; in high concentrations it depresses.

The peculiar relation of starch to variation in the pH of the medium must also be noted. It entirely suppresses the flotation of fluorite in both acid and alkaline media. This phenomenon is apparently to be explained by the transition of the starch in such media into a more soluble state with consequent increase of its depressant activity.

Dextrin, however, in spite of the similarity between its physicochemical properties and those of starch, continues to act as an activator in concentrations as high as 1000 grams per ton.

In the presence of dextrine, flotation of fluorite increases in an alkaline medium, but falls almost to zero in an acid medium.

Glucose slightly depresses the flotation of fluorite. In the presence of glucose, this flotation is suppressed in an acid medium, but on transition to an alkaline medium, it rapidly rises to reach almost total recovery of the mineral. In the latter case the strong activating effect of the alkali itself plays a role.

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Figure 10. Flotation of fluorite in the presence
of carbohydrates

Side axis -- γ %

Bottom axis -- Concentration in grams per ton

1 -- starch 2 -- dextrin 3 -- glucose

Figure 11. Flotation of fluorite in the presence
of carbohydrates with varying pH of the medium

Side axis -- Yield in %

Bottom axis -- pH

1 -- starch 2 -- dextrin 3 -- glucose

Figure 12. Flotation of fluorite in the presence
of tannin and sulfite liquor

Side axis -- γ %

Bottom axis -- Concentration in grams per ton

1 -- tannin 2 -- sulfite liquor

Figure 13. Flotation of fluorite in the presence
of tanning and sulfite liquor with varying
pH of the medium

Side axis -- Yield in %

Bottom axis -- pH

1 -- tannin 2 -- sulfite liquor

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Of the tanning agents, tannin and sulfite liquor were selected for study of their flotational influence on fluorite.

Tannin is the glucoside of digallic acid, and there are numerous phenolic hydroxyl groups [i.e., hydroxyl groups attached to a benzene ring] in its structure. Its ability to stabilize mineral suspensions, especially in alkaline media, is a characteristic property of tannin.

Sulfite liquor is a product of processing the alkaline liquor obtained when wood is treated with calcium bisulfite. Its active material consists mainly of lignin-sulfonic acid. This acid, whose chemical constitution is not precisely known, is employed as a stabilizer of mineral suspensions. Its gold number is not known. It is analogous to tannin in its hydrolyzability, especially in an alkaline medium.

In view of the instability (hydrolysis) of aqueous solutions of tannin, we always use freshly prepared solutions -- as with proteins -- in flotation experiments.

Figure 12 and 13 show the experimental data on the effect of tannin and sulfite liquor on the flotation of fluorite.

Tannin and sulfite liquor exhibit a sharp difference in their behavior to fluorite. Tannin is a powerful depressant, which already acts at concentrations of 250 grams per ton, while flotation is completely inhibited at levels of 1,000 grams per ton.

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Sulfite liquor strongly activates fluorite at concentrations as low as 100 grams per ton, which level gives almost total extraction.

In the presence of tannin (250 grams per ton) the flotation of fluorite does not proceed in either an acid or an alkaline medium, which indicates the sharp increase in the depressant action of tannin in such media. In the presence of sulfite liquor, the flotability of fluorite is likewise diminished in acid and alkaline media, but the effect of this liquor is considerably weaker.

Lyuyken and Birbrauer [15] observe that a number of para-compounds exert a depressant influence on flotation. In connection with this the influence of paranitrophenol and paraaminophenol, the latter in the form of its hydrochlorides on fluorite flotation was studied. At the same time the action of sulfosalicylic acid was studied. Figure 14 and Table 23 show the results.

Figure 14. Flotation of fluorite in the presence of: paraaminophenol, paranitrophenol and sulfosalicylic acid.

Vertical axis -- γ %

Horizontal axis -- Concentration in grams per ton

- 1 -- paranitrophenol
- 2 -- paraaminophenol
- 3 -- sulfosalicylic acid

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TABLE 23

Flotation of Fluorite in the Presence of Para-Compounds
at Varying pH of the Pulp

Concentration in grams per ton		Aminophenol hydro- chloride, 250 grams per ton		Nitrophenol, 250 grams per ton		Sulfosalicylic acid, 250 grams per ton	
HCl	NaOH	pH of pulp	Yield in %	pH of pulp	Yield in %	pH of pulp	Yield in %
100	—	4.2	0.5	4.5	0.7	—	—
—	—	4.9	58.6	5.7	87.5	4.1	1.2
—	—	7.3	92.6	8.7	95.9	7.1	97.3
—	250	11.4	98.8	no experiment		11.4	98.0
—	2,500						

Paraaminophenol hydrochloride is a weak activator in fluorite flotation. The activating effect of this para-compound rises sharply in an alkaline medium but falls in an acid one.

Paranitrophenol strongly activates fluorite flotation in neutral and alkaline media, while in an acid medium this flotation does not proceed at all in its presence.

Sulfosalicylic acid gives a strongly acid medium and suppresses the flotation of fluorite. In a weakly alkaline medium the flotability of fluorite in the presence of sulfosalicylic acid rises almost to total extraction of the mineral.

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The experimental data above presented on the flotation of fluorite in the presence of a number of inorganic and organic compounds furnishes adequate material for controlling that flotation. A number of powerful inorganic and organic depressants have been discovered, and likewise a number of activators of fluorite have been found. The combination of separate compounds gives research workers and concentration practice sufficient means for solving the problems which may come up in the flotation of fluorspar ores.

THE DIFFERENTIAL FLOTATION OF FLUORITE,
BARITE AND CALCITE

Quartz, calcite, barite, and the metallic sulfides are the principal components of fluorspar ores. There is no particular difficulty in separating the sulfides during the concentration of these natural mineral associations. The sulfides are floated by xanthates, which are not collectors towards fluorite. The separation of the quartz also causes no trouble. Sodium silicate is an excellent suppressor for quartz and when used in the presence of moderate amounts of oleic acid, interferes with the ability of quartz to float, and, at the same time, depresses fluorite very slightly or not at all, if its own concentration (that of the silicate) is at the proper level.

The differential flotation of fluorite and barite or calcite, however, encounters formidable obstacles. These

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In 1930, Williams and Greeman took out a patent for the separation by flotation of fluorite from barite and calcite, using a tedious method of desliming the ore and then using oleic and cresylic acids, both at the rate of 0.15 kilograms per ton, for its flotation. Under laboratory conditions, good results were obtained by desliming the slurry of suspended particles three times after five minutes standing. The results of three experiments, of which only the first can properly be applied to the separation of fluorite from calcite, are given in Table 24. This method of separating fluorite and calcite involves large slime losses even under laboratory conditions. The mineralogical characteristics of the components of the ores are insufficiently clear, in particular, it is not stated whether or not the calcite used in the first experiment was silicified. A french patent of 1929 [No 682250 of 24 September] also proposes the separation of the slime, followed by flotation with oleic acid and cresol, for separating fluorite from calcite.

Professor Goden mentions another method of separating fluorite from calcite on a laboratory scale [7]. A mixture of elutriated powdered calcite and fluorite is treated with a strong solution of copper sulfate, carefully washed, and then subjected to flotation in the presence of amyl xanthate. The calcite is floated first of all, with the formation of the characteristic yellow film of copper xanthate on its surfaces. The consumption of the agents is very high. In practice, in 1932, according to Goden, the flotation was unsuccessful in separating fluorite from calcite.

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TABLE 24

Separation of Fluorite by Flotation from
Calcite and Quartz

Products	Content in percent			Recovery in percent	
	CaF ₂	SiO ₂	CaCO ₃	CaF ₂	CaCO ₃
Mill feed	70.80	6.00	21.50	100.0	100.0
Concentrate	98.07	0.15	1.20	70.6	—
Slime	—	—	—	21.1	31.5
Mill feed	80.50	9.0	5.0	100.0	100.0
Concentrate	99.27	0.03	0.43	73.5	—
Slime	—	—	—	26.4	43.3
Tailings	—	—	—	0.1	—
Mill feed	57.80	35.80	1.40	100.0	100.0
Concentrate	99.5	0.17	0.28	83.3	—
Slime	—	—	—	8.7	31.6
Tailings	—	—	—	8.0	—

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The MEKhanOBR made an attempt to separate fluorite from barite in 1931, in the course of tests on the amenability of the Vadam fluorspar ores to concentration. Oleic acid and kerosene were used as flotation agents, sodium silicate as depressant, and pine oil as foaming agent.

The results proved entirely unsatisfactory because of difficulties that developed /10/. Table 25 gives the results of typical experiments.

TABLE 25

Flotation of Barite-Fluorite Ores of the Badam Deposit

Products	Yield in percent	Content in percent		Recovery in percent	
		CaF ₂	BaSO ₄	CaF ₂	BaSO ₄
Concentrate	28.64	55.37	29.40	37.80	30.60
Tailings	71.36	37.42	26.51	62.20	69.40
Mill Feed	100.0	41.93	27.50	100.0	100.0
Concentrate	27.97	15.46	74.15	29.70	31.80
Tailings	72.03	14.22	61.70	70.30	68.20
Mill Feed	100.0	14.56	65.18	100.0	100.0

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A new method for the differential flotation of fluorite and barite was worked out in 1934 by M. A. Eygeles of the IMS; for fluorite and calcite in 1935. Of the two possible methods for differential flotation, choice of a collector with selective action or choice of a depressant with selective action, the Institute of Economic Mineralogy chose the latter direction. This did not mean rejecting the possibility of a selective action collector. However, the brilliant successes in the differential flotation of sulfide minerals, based on the selective action of depressants, together with the numerous failures of attempts to find selective action collectors for a number of non-sulfide minerals [Goden writes ("Flotation"), page 328 of the translation): "The efforts to reduce the force of the action of the collector on the minerals (fluorite and calcite) in the hope of finding conditions under which the reaction would proceed only with a single one of them, proved unsuccessful. These attempts were made both by controlling pH and by using various fatty acids with relatively short CH chains."⁷, and also most important of all, theoretical considerations, forced us to consider the choice of selective depressants as the shortest and most promising method. Present views on the mechanism of the flotation process for non-sulfide ores establish the existence of a chemical union between the collector (carboxylic acids) and the cations of the crystal lattice of the mineral. In view of the similarity of the chemical properties of the cations Ca^{++} and Ba^{++} in one pair of minerals (fluorite and barite), and of

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the identity of the cations in the other pair (fluorite and calcite) it becomes a very complicated business to set up the conditions for any selective reaction between them. A significant role is played, in the processes of depression by electrolytes or colloids, by the adsorptive processes upon the mineral faces, upon which there can be no doubt that the difference in the types of ionic crystal-lattices of each pair of minerals exercises an marked effect in a number of instances.

Determination of a rational connection between the individual flotability of minerals and their flotability in mixtures met formidable obstacles. It has been generally known for a very long time that the conditions for flotation of a mineral by itself are not directly applicable to its mixtures with other minerals. Glover formulates this position as follows: "If a mineral is floated by any combination of agents used in certain amounts, while another mineral is not floated under these conditions, it does not necessarily follow that these minerals can be separated from each other by using the same combination of agents in the same amounts [47]." In investigating the flotability of minerals from their mixtures, Eygeles came to adopt the following position, based on the experimental data.

In the flotation of a mixture of polar minerals, the ions of the minerals or ores in question pass over into the solution, or pulp. The presence of these "unavoidable" ions

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in the pulp creates new conditions of flotation, different from those under which the flotation of the pure minerals took place, and results on the whole in a modification of the flotational behavior of the minerals during flotation of mixtures or ores. Even such difficultly soluble minerals as barite, fluorite and calcite enter into solution in very appreciable quantities under such conditions. The data on the solubility of these minerals, according to Landolt, are presented in Table 26.

The last column of Table 26 shows that the content of dissolved minerals in the pulp may be high under ordinary flotation conditions, with the solids: liquid ratio, or pulp consistency of 1:6 and with the method of calculating in grams per ton of mineral that is usual in flotation practice.

As may be seen from these data, the degree of saturation of the pulp with the ions resulting from the solubility of the so-called insoluble minerals is of the same order as the pulp's content of ions introduced into it during flotation in the form of dissolved salts, for depressant flotation at concentrations as low as 50 grams per ton. The CaCO_3 content that the dissolved calcite produces in the pulp exceeds this amount, while the BaSO_4 content from the dissolved barite is close to it. The marked changes in solubility in the presence of salts must also be taken into account.

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Table 26

SOLUBILITY OF BARITE, CALCITE AND FLUORITE IN WATER			
Minerals	T in degrees Centigrade	Solubility in grams per liter	Content in the pulp in grams per ton, at pulp consisting of 1:6
Fluorite	18	0.015	90
Barite	20	0.0024	15
Calcite	25	0.014	84

Yield in %

Quantity of oleic acid in grams per ton.

1. Flotation of Fluorite. 2. Flotation of Barite

*Figure 16. Flotation of fluorite and barite with
varying quantities of oleic acid.*

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If we assume that the action of calcium fluoride produces a certain increase in the natural solubility of barite and calcite, the quantity of unavoidable ions entering the pulp from the minerals being floated still more closely approaches that of the ions introduced by charging it with salts in significant and active amounts.

In the flotation of a mixture of fluorite and barite, or of fluorite and calcite, the unavoidable ions in the pulp are the Ca^{++} , Ba^{++} , SO_4^{--} and F^- ions and the Ca^{++} , CO_3^{--} and F^- ions respectively. The experimental data on the separate flotation of fluorite show that the SO_4^{--} and CO_3^{--} ions act as activators in this process. The influence of these unavoidable ions on the flotation of barite and calcite has been shown to be weakly activating by a series of individual flotation experiments for these minerals in presence of salts containing such ions. Thus, on the basis of these considerations, the flotability of fluorite from its mixtures with barite and calcite could reasonably be expected to be considerably better than that of pure fluorite. Let us consider the case of fluorite and barite.

Individual flotation with oleic acid is more active for barite. Barite gives a considerably higher yield of concentrate for identical quantities of oleic acid, as may be seen from Figure 16. An experiment with fractional removal of the concentrate, conducted under the same conditions

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for barite and fluorite, confirms the greater intensity of flotation for barite. (This relation between the flotabilities of fluorite and barite is not invariably encountered, and depends on the quantity and quality of the minerals in the mixture, especially of their soluble portions.)

Table 27

Minerals	pH of the Pulp	Concentrate	Yield of Concentrate in Percent
Fluorite	6.3	I	3.2
		II	8.5
		III	18.1
		IV	10.7
		V	4.5
Barite	6.0	I	3.9
		II	16.1
		III	30.2
		IV	23.6
		V	5.8

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In flotation of a mixture of fluorite and barite, on the contrary, concentrates containing more fluorite than barite are obtained, confirming the views expressed as to the activation of fluorite by ions resulting from the solution of barite. The results of one of the experiments in flotation of a mixture of 40 percent fluorite, 40 percent barite, and 20 percent quartz, are shown in Table 28.

Table 28

Charge of oleic acid in grams per ton	pH of the pulp	Yield of Con- centrate in Percent	Content in Percent			Recovery in Percent	
			CaF ₂	BaSO ₄	SiO ₂	CaF ₂	BaSO ₄
50	6.2	37.2	64.4	33.7	1.2	59.9	31.3
75	6.1	71.0	55.6	39.9	3.1	98.7	70.8
Original mixture			40.0	40.0	20.0	100.0	100.0

The Institute of Economic Mineralogy (Eigheles) used a new method of research in experimentally confirming the influence of the unavoidable ions on fluorite flotation: flotation in aqueous filtrates of minerals and ores. These filtrates were prepared by agitation of the deslimed fine-grain fractions of minerals and ores in a laboratory flotation machine.

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The time of agitation was the same as the usual flotation time for the minerals. The solutions obtained were decanted, filtered, and then carefully allowed to stand to free them of all suspended particles. [Evidently the tacit assumption is here made that the desliming -- not described in detail -- had already removed all particles of colloidal size, which would otherwise remain in permanent colloidal suspension.] These filtrates, representing mineral solutions, were then used, together with added water, for the flotation of individual minerals. In the flotation of fluorite a number of other filtrates of pure barite and barite-fluorite ore of the Badam deposit were tried. Table 29 shows the results of a number of flotation experiments on fluorite and barite in water, in aqueous filtrates, and in the presence of ions that activate fluorite. Each pair of experiments entered in a single vertical column of the table was performed under entirely identical conditions.

The data of Table 29 allow us to ascribe the activation of fluorite that takes place in flotation of a fluorite-barite mixture to the dissolved portion of the barite, owing to the passage of its ions into solution. More detailed study shows this effect to be mainly due to the SO_4^{--} ion. The activation of barite by the ions of fluorite is very weak, and is therefore not reflected in the results of flotation of fluorite-barite mixtures.

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Table 29

Conditions of flotation	Yield of Concentrate in % from fluorite flotation			Yield of Concentrate in % from barite flotation		
	Experiment Number					
	1	2	3	4	5	6
Flotation in water	5.2	42.3	63.7	22.5	34.9	74.9
Flotation in barite solution	25.2	77.8	-	-	-	-
Flotation in so- lution of Badam fluorite-barite ore	-	-	94.9	-	-	-
Flotation in presence of 50 grams of Na ₂ SO ₄ per ton	-	-	-	50.2	-	-
Flotation in fluorite so- lutions	-	-	-	-	41.3	79.3

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The selectivity due to the unavoidable ions remains, however, very low. There is a large amount of barite in the fluorite concentrate. To bring about the differential flotation of fluorite and barite, the pulp was charged with compounds acting in the same direction as the aggregate of the unavoidable ions, i.e. as activators of fluorite and simultaneous depressants of barite. Investigation of the relative flotabilities of fluorite and barite enabled Eigheles (IMS) to locate such compounds. Of the compounds tried, potassium chromate, permanganate and perchlorate, and dextrin, as well as sulfite liquor, all gave good results.

Potassium chromate sharply activates fluorite. At the same time it depresses barite in charges as low as 50 grams per ton, and gives excellent results with respect to selectivity even if only a single flotation, without a purifying flotation, is run. The extraction of fluorite is entirely satisfactory and attains 94.2 percent for both concentrates. The barite concentrate was obtained by charging the pulp with caustic soda to increase its pH and simultaneously adding a small amount of oleic acid (50 grams per ton). Table 30 gives the results of one of these flotation experiments under the conditions stated.

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Table 30

Flotation of a mixture of fluorite, barite
and quartz

Use of agents		Products	Yield in %	Content in %			Recovery in %		
in grams per ton	pH of pulp*			CaF ₂	BaSO ₄	SiO ₂	CaF ₂	BaSO ₄	SiO ₂
K ₂ CrO ₄ -1000	-	Concentrate I	40.7	98.1	0.96	0.77	99.8	1.0	1.6
Oleic acid -500									
Caustic soda;									
Oleic acid -50	-	Concentrate II	39.0	0.2	93.6	4.4	0.1	91.2	8.6
	12.2	Tailings	20.2	0.2	15.4	88.9	0.1	7.8	89.8
Mixture of powdered minerals (100-250 mesh)			40	40	20		100	100	100

[* Text says "of pulp"; presumably "pH" was omitted by printer's error.]

The results obtained by the initial flotation were exceptionally high. The fluorite concentrate contained 98.1 percent of CaF₂, with recovery in it of 99.8 percent of the total fluorite in the sample. The initial barite concentrate contained 93.6 percent of BaSO₄, with recovery of 91.2 percent. The contamination of the concentration by quartz was very low, amounting to only 0.77 percent for the fluorite concentrate and 4.4 percent for the barite concentrate.

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Table 31 shows the results of a number of flotation experiments with fluorite-barite mixtures, using various agents. They demonstrate that there are enough media at the disposition of concentrators for use in the differential flotation of fluorite and barite. ~~Fluorite and barite are equally amenable to differential flotation by means of oleic acid.~~

Table 31

Initial flotation of fluorite-barite mixtures with oleic acid in the presence of various depressants for barite.

Use of depressants in grams per ton	Products	Yield		Content in %		Recovery in %	
		in %	CaF ₂	BaSO ₄	CaF ₂	BaSO ₄	
Chromium nitrate 250	Concentrate	39.5*	82.9*	15.6	81.7	16.3	
Potassium bichromate 1000	Concentrate I	30.7*	93.4*	5.2	71.6	4.0	
	Concentrate II	10.5	86.3	11.8	22.7	3.1	
Sulfuric acid 100	Concentrate I	34.2	98.6	1.4	67.5	0.9	
Dextrine 250	Concentrate I	24.6	94.6	5.4	46.7	2.6	
	Concentrate II	26.5	84.2	15.8	43.0	8.1	
Sulfite liquor 250	Concentrate	50.2	95.53	4.47	96.1	4.5	
	Tailings	49.8	3.8	92.2	3.9	95.5	
Iron-ammonium alum 250	Concentrate	32.1	95.4	4.6	61.2	3.0	
	Middlings	17.4	78.6	21.4	27.4	7.4	
	Tailings	50.5	11.3	88.7	11.4	89.6	
Potassium perchlorate 1000	Concentrate	41.6	95.4	4.6	79.4	3.8	
	Tailings	58.4	17.2	82.8	20.6	96.2	
Calcium sulphate 250	Concentrate	45.3	97.4	2.6	88.3	2.3	

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Note. Mixtures of 40 percent fluorite, 40 percent barite and 20 percent quartz were used in experiments marked with an asterisk (*). Mixtures of 50 percent fluorite and 50 percent barite were used in all the others. The powders were of 100-250 mesh coarseness.

It appeared of great interest to elucidate the influence of the fines on the flotation of powdered minerals. For this purpose a series of experiments was run, with various quantities of fine fluorite and barite (under 250 mesh) added to the mixture. The results of this series of experiments, conducted under the usual conditions for differential flotations, are presented in Table 32.

In experiments 1, 2 and 3, 1000 grams of potassium chromate per ton were used as a depressant. Fifty grams of oleic acid per ton were used for the first and second fluorite concentrates, while to obtain the barite concentrate the pulp was charged with enough caustic soda to bring its pH up to 12, together with 50 grams of oleic acid per ton. The optimum pH of the pulp for barite flotation was not determined with adequate precision. In experiment 4 the charge of potassium bichromate was increased to 2000 grams per ton, the other conditions remaining unchanged.

The data of Table 32 demonstrates rather convincingly that the presence of fines in powdered minerals to be floated introduces no fundamental new factor into the flotation con-

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ditions. With the increase in the total area of the mineral particles the amount of agents used must merely be increased, which is entirely normal in flotation practice.

Table 32.

Differential flotation of a fluorite-barite mixture in the presence of fines.

Experiment No.	Composition of the powdered fluorite-barite mixture in %		Products	Yield in %	Content in %	
	100-250 mesh	under 250 mesh			CaF ₂	BaSO ₄
1	90	10	Concentrate I	50.4	94.1	5.9
			Concentrate II	47.5	3.5	96.5
2	80	20	Concentrate I	23.0	79.6	20.4
			Concentrate II	27.3	96.9	3.1
			Concentrate III	47.3	2.2	97.8
3	50	50	Concentrate I	24.0	99.9	0.1
			Concentrate II	27.6	78.8	21.2
			Concentrate III	45.8	93.8	96.2
4	50	50	Concentrate I	32.4	99.1	0.9
			Concentrate II	20.4	89.7	10.3
			Concentrate III	44.1	3.9	96.1

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The experimental data above presented on the results of the differential flotation of fluorite-barite mixtures testify to the availability of the necessary means for working out the conditions for differential flotation of fluorite-barite ores.

The development of the methodology of differential flotation of fluorite and calcite proceeded in the same general direction. Separation of these minerals by flotation proved more complicated than that of fluorite and barite. In its flotation properties calcite occupies a position intermediate between fluorite and barite, but still rather closer to barite.

Study of the mutual influence of fluorite and barite on their respective flotations showed that the unavoidable ions in the mixture activate the flotation of fluorspar and act on calcite flotation to a considerably lesser extent. This was confirmed by flotations in calcite filtrates by methods described above.

The activation of fluorite by the ions of the mixture was also confirmed by the flotation results for fluorite-calcite mixtures. Table 33 shows the results of one of these experiments performed without using any depressant at all.

Table 33

Flotation of a fluorite-calcite mixture with oleic acid

Use of oleic

acid in grams per ton	Products	Yield in %	Content in %	
			CaF ₂	CaCO ₂
25	Concentrate I	67.7	61.3	38.7

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The methodology of differential flotation of fluorite and calcite has been worked out along the same general lines as that for fluorite and barite, i.e. by selecting agents that depress calcite and at the same time activate fluorite. There are fewer such selective depressants for calcite, which is entirely natural in view of the great similarity between the properties of calcite and fluorite. When such depressants are employed, concentrates containing over 90% of fluorite are obtained from an initial flotation of a mixture of powdered fluorite and calcite of 100-250 mesh coarseness.

It follows from what has been set forth above that the Institute of Economic Mineralogy (IMS) has worked out a methodology for a separating fluorite, barite and calcite by flotation. A number of inorganic and organic agents have been found to act as selective depressants for barite and calcite and simultaneously as activators for fluorite. The combination of these agents allows the differential flotation of complex mineral associations.

A method of separating fluorite and calcite, using a different principle, has been developed by the Vaychag Laboratory in its tests of the amenability to concentration of the carbonate-fluorite varieties of fluorspar from the Amderma deposit. This is a fluorspar with partially silicified limestones. The Laboratory chose a selective-action collector and obtained favorable results in a number of cases. The compounded collectors tested by it gave good separation in the concentration of fluorspar with 19 to 21 percent of calcium carbonate.

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The flotation with Agent No 2 of ore containing 46.4 percent of fluorite and 21.4 percent of calcium carbonate, by a system consisting of one rougher and two cleaner flotations, yielded, under optimum conditions, a concentrate with 88.1 percent fluorite and 9.1 percent calcium carbonate.

No data has been published on the results of the initial flotation which would permit comparison with the results presented above.

In flotation of pure calcite and limestone, agent II, used in conjunction with potassium permanganate, proved to be less selective than oleic acid.

The selective action of Agent No 3 appears to be very great. Results for the initial flotation are unavailable. The scheme included one initial and two refining flotations, and its results are shown by Table 34.

Table 34

Flotation of Amderma fluorspar

Agents used	Products	Yield in %	Content in %			Recovery of CaF ₂ in %
			CaF ₂	SiO ₂	CaCO ₃	
Sodium silicate	Mill feed	100.0	48.6	28.7	21.4	100.0
1 kg. per ton						
Agent No 3						
0.3 kg. per ton	Concentrate	47.0	97.1	0.8	1.2	93.8
Distilled turpentine						
0.08 kg. per ton	Tailings	53.0	5.7	52.4	39.2	6.2

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Flotation of ore with 47.5 percent CaF_2 and 19.1 percent CaCO_3 yielded a concentrate with 97.5 percent CaF_2 and 1.0 percent CaCO_3 , with 92.4 percent of the total fluorite recovered in the concentrate.

These results are much higher than those obtained by Williams and Greeman in their method of flotation with oleic and cresylic acids after preliminary desliming. (See Table 24.)

FLOTATION AGENTS FOR FLUORITE

The flotation of fluorite, like that of many other non-metallic minerals, is done by using carboxylic acids as collectors. In practice, oleic acid or its sodium soap, sodium oleate, are the only collectors whose use is well known in fluorspar flotation mills in actual operation. The flotation of pure fluorite with oleic acid under various conditions is discussed in detail in the chapter "Flotation of fluorite". Oleic acid gave most satisfactory results in testing the amenability of our ores to flotation, and left no doubt as to the possibility and technical expediency of its use as a collector for fluorspar. These materials will be presented in detail below.

Sodium oleate gave less favorable results in a number of cases.

At the same time there are a number of substantial disadvantages in using oleic acid as a collector. The principal objections are the varying quality of the technical product, its sensitiveness to the pulp temperature, its marked sensitiveness

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to the pH of the pulp, and its high cost.

The results of the rougher flotation of Solonechnoye fluorspar under the same conditions, using the same amounts of collector, but using oleic acid from different batches of the technical product, are presented in Table 35 to illustrate this lack of uniformity in technical oleic acid.

Table 35

Flotation of Solonechnoye fluorspar with technical oleic acid from
different batches

Experiment	Products	Yield in %	CaF ₂ content in %	CaF ₂ Recovery in %
1	Concentrate	57.1	95.2	66.4
	Middlings and tailings	42.9	65.5	33.6
2	Concentrate	67.0	95.1	77.8
	Middlings and tailings	33.0	55.0	22.2
3	Concentrate	59.3	92.8	67.5
	Middlings and tailings	40.7	65.6	32.5
Mill Feed		100.0	81.7	100.0

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This data indicates not only a varying degree of recovery and, consequently, fluctuation in the quantity of the collector that must be used, but, as may be seen from their experiment, it even shows considerably fluctuation in the selective action of oleic acid.

Some data on the influence of pulp temperature on flotation efficiency with oleic acid are shown in Figure 2 (p. 224).

Increasing pulp temperature not only increases the recovery of fluorspar into the concentrate, but also increases the selectivity of the action of oleic acid.

Figure 3 gives an adequate idea of the high sensitivity of oleic acid to the pH of the pulp.

These objections to the employment of oleic acid, especially those connected with its being in short supply, led to the initiation of a number of projects to discover new collectors for use as flotation agents for fluorspar.

A considerable number of these researches were conducted in the Institute of Economic Mineralogy (Eigheles), and some in the Institute of Non-Ferrous Metals (Linchevskiy) and in the Vaychag Laboratory of the GLAVSEVMORPUT' (Gal'perin.) In the course of this work, tests were made on the oxidation products of paraffin, the oxidation products of solar oil, the sulfonaphthenic acids (according to Petrov), the naphthenic acids, peat tar, etc.

The following are the most important properties in the

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choice of a collector: (a) high selectivity towards fluorite in the flotation of its ores containing calcite, barite, quartz and the oxidized heavy-metal minerals; (b) low sensitivity to pulp temperature; (c) stability of action throughout a definite range of pulp pH; (d) high mineralization of the froth and its breakdown within normal periods; (e) convenience in charging, simplicity and uniformity in composition; (f) absence of frothing properties.

The agents studied do not come anywhere near possessing all these properties. All of them are sensitive to pulp temperature and all of them froth.

Oxidized paraffin is a product obtained by the oxidation of Groznyi paraffins by passing a stream of air through it at a temperature of about 160 degrees Centigrade. After removal of the more volatile oxidation products (hydrocarbons, aldehydes and lower fatty acids) oxidized paraffin wax remains in the reaction chamber. It is composed of higher carboxylic acids and oxy-acids (the saponifiable part) and unoxidized hydrocarbons (the unsaponifiable part). A mixture of carboxylic acids is removed by benzine as a solvent from the oxidized paraffin wax. The oxy-acids and the unoxidized fraction of the paraffin are not dissolved by benzine. The oxidized paraffin tested has an acid number of the order of 140 and a saponification number of 310. The carboxylic-acid mixture has a acid number of the order of 136.5 and a saponification number of 182.5.

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The flotation properties of the oxidation products of paraffin were established by the researches of Professor Rebinder's laboratory, and were investigated by IMS on Kalangui fluorspars [14,17,23].

Figure 17. Effect of temperature on the flotation of fluorite with oxidized paraffin.

- 1: content β in the concentrate
- 2: recovery ϵ in the concentrate.

Oxidized paraffin is a substance of pasty consistency and is very difficult to charge into the flotation machine without a solvent. After charging it floats on the surface of the pulp.

The highest fluorite content in the concentrate was obtained by the use of benzine as a solvent. The recovery was the same when a mixture of benzine and benzol was used. Kerosene as a solvent gives the poorest recovery and the poorest quality of the concentrate. Flotation at the increased temperature of 21 to 22 degrees Centigrade increases the recovery in the concentrate and preserves the former relation between the effects of the solvents. Kerosene as a solvent also gives the poorest recovery in this case, while benzine gives the best.

The good solubility of the fatty acids in benzine makes flotation conditions best when it is used. When kerosene, on the other hand, is used, a considerable part of the active components of the paraffin is removed from the sphere of activity.

Therefore, in spite of certain technical inconveniences

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associated with the use of benzine solutions, benzine is nevertheless employed as a solvent.

A series of experiments using varied amounts of caustic soda was run to ascertain the optimum alkalinity of the pulp in fluorite flotation with oxidized paraffin.

The best results were obtained when caustic soda was used at the rate of 350 grams per ton, which yielded a CaF_2 content of 91.7 percent in the concentrate, with recovery of 95.2 percent therein.

Oxidized paraffin is at the same time a collector and a foaming agent. The effect of increasing the usual amount of pine oil as a foaming agent was studied experimentally. The recovery of fluorite in the concentrate increases with the amount of pine oil used. At the same time the quality of the concentrate was slightly impaired. Flotation also proceeds without the pine oil, but its use in moderate quantities (about 60 grams per ton) is most expedient, as it increases the recovery.

Concentration of oxidized paraffin (in benzine)
Figure 18. Effect of the concentration of oxidized paraffin (in benzine solution) on fluorite flotation. Concentration of oxidized paraffin (in benzine)

- 1: CaF_2 content in the concentrate
- 2: CaF_2 recovery into the concentrate

During flotation with oxidized paraffin, the depression of quartz was perfectly normal when sodium silicate was used at very

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much the same rate established for oleic acid flotation.

Pulp temperature exerts considerable influence on fluor-spar flotation with oxidized paraffin, which congeals slightly at lower temperatures, sharply diminishing its flotation activity. Figure 17 shows the results of the flotation of Kalangui fluorspar with oxidized paraffin, under the same conditions, but with varying pulp temperature.

Pulp temperature of 23 to 24.5 degrees Centigrade give the best results. Further increase in pulp temperature does not improve the course of flotation, while reduction of temperature sharply reduces recovery. The possibility of using oxidized paraffin in the form of a strong benzine solution was tested in a number of experiments, at varied concentration of the agents. The results, presented in Figure 18, show that it is possible to increase the concentration of the benzine solution of the collector without sharply impairing the quality of the concentrate. However, when the concentration of oxidized paraffin in its solution exceeds 20 percent, there is a sharp fall in the recovery of fluorite into the concentrate.

The carboxylic acids prepared from oxidized paraffin possess the same properties as that substance itself. The introduction of these acids into the pulp also requires a solvent, since they are also of paste-like consistency. The best solvent is benzine, but kerosene will also do very well.

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The influence of the temperature factor on flotation with the carboxylic acids proves to be the same as with oxidized paraffin. A pulp temperature of 23 to 24 degrees Centigrade corresponds to optimum flotation. It is possible to use kerosene solutions containing up to 30 percent of carboxylic acids. Pine oil increases the recovery of fluorite and slightly reduces the quality of the concentrate.

Table 36 shows the results of a detailed study of Kalangui fluorspar with the oxidation products of paraffin. The scheme consisted of one rougher flotation and two cleaner flotations.

Table 36

Flotation of Kalangui fluorspar with the oxidation products of paraffin.

Collector	Product	Yield in %	CaF ₂ Content in %	CaF ₂ Recovery in %
Oxidized				
Paraffin	Concentrate	49.0	96.86	70.90
	Middlings	19.60	69.00	19.90
	Tailings	31.40	18.88	9.20
	Mill Feed	100.00	67.00	100.00
Carboxylic				
Acids	Concentrate	48.80	96.08	72.5
	Middlings	22.80	60.0	20.40
	Tailings	28.40	15.55	7.10
	Mill Feed	100.00	64.69	100.00

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Comparison of the flotation results with oxidized paraffin and the carboxylic acids with those of oleic acid shows that both these oxidation products of paraffin can serve as substitutes for oleic acid. The carboxylic acids have the advantage over oxidized paraffin that they can be used in more concentrated solutions (30 percent) and at lower pulp temperatures, down to 12-14 degrees, to obtain a completely finished concentrate. The necessity for using both these agents in the form of dilute solutions [rather than directly] is a significant fault in both of them, and very sharply curtails their use.

The above-mentioned production of oxidation products of paraffin gave them a certain interest as high-quality substitutes for oleic acid. At the present time these oxidation products are not being produced on an industrial scale and hence there is no longer any possibility of using them in flotation practice.

Oxidized naphtha oil is an oxidation product of solar oil which has been subjected to preliminary treatment with concentrated sulfuric acid. The oxidized oils produced by the Konstantinovsk and Kazan plants imeni Vakhitov were tested as flotation agents. Their composition and characteristics were as follows.

Oxidized oil of the Kazan plant: acid number, 120; saponification number, 140; unsaponifiable matter, 17.7 percent; acids (including oxy-acids), 63.8 percent; oxy-acids, 20.2 percent.

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Oxidized oil of the Konstantinovsk plant: unsaponifiable matter, 15.7 percent; acids (including oxy-acids), 72.9 percent; oxy-acids, 19.6 percent.

Study of the flotation characteristics of these oxidized oils with Kalangui and Solonechnoye fluorspars showed that entirely finished concentrates with normal recovery could be obtained by flotation using such oils.

The pH of the pulp affects flotation less drastically with oxidized solar oil than with oleic acid, but it still remains one of the basic factors that influence the course of flotation. The optimum pulp pH for flotation with oxidized solar oil is lower than with oleic acid, thus requiring a lower consumption of caustic soda. In cases where the pulp is charged with considerable amounts of sodium silicate in order to depress the quartz, even acids may be charged into the pulp during fluorspar flotation, thus reducing the alkalinity of the medium. Thus in flotation of Kangalui fluorspar with oxidized oil from the Konstantinovsk plant, rather good results were obtained from the primary flotation when a small amount of acid was charged. The best results from charging with alkali and acid, using sodium silicate and the collector at the respective rates of 700 and 500 grams per ton, are shown in Table 37.

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Table 37

Flotation of Kalangui fluorspar

Consumption of agents

in grams per ton		Products	Yield	Content	CaF ₂ Recovery in %
HCl	NaOH		in %	CaF ₂ in %	
135	-	Concentrate	72.8	82.45	92.8
		Tailings	27.2	18.71	7.2
-	1900	Concentrate	75.6	82.40	96.2
		Tailings	24.4	10.09	3.8
-	-	Feed	100.0	64.69	100.0

The depression of quartz is produced, as usual, by charging the pulp with sodium silicate, of which the consumption is no different than with other collectors. The addition of a foaming agent has no appreciable effect on the flotation, since the foam-producing capacity of oxidized oil is very high.

The mineralization of the foam in flotation with oxidized solar oil approximates that with oleic acid. Study of the mineralization of the foam in laboratory MZ machines revealed the marked influence of the quantity of collector-foaming agent on it, for with an oxidized-oil charge of 200 grams per ton the solids-content of the foam was 36.4 percent, while when the charge was increased to 400 and 1000 grams per ton, the solids-content fell to 32.7 percent and 29.1 percent respectively.

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Concentrates with 96 percent to 98.5 percent of CaF_2 were obtained from flotation of Solonechnoye fluorspar. The data of a few rougher flotation experiments are shown in Table 38. The consumption of agents amounted to: caustic soda, 600 grams per ton; sodium silicate, 300 grams per ton; collector, 200 grams per ton.

Table 38

Flotation of Solonechnoye fluorspar with oxidized solar oil

Products	Yield in %	CaF_2 content in %	CaF_2 recovery in %
Concentrate	71.0	96.17	96.6
Tailings	29.0	8.28	3.4
Concentrate	69.2	98.1	95.8
Tailings	30.8	9.7	4.2
Flotation feed	100.0	70.7	100.0

As may be seen from the analysis above presented, the principal constituents of the oxidized solar oil are the mixture of carboxylic acids and the oxy-acids.

To determine what was the most active part of the oxidized

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solar oil, the flotation properties of its fractions were studied: the mixture of carboxylic acids and the oxy-acids. The former is a very viscous slow-moving liquid that readily congeals when the temperature falls. It was charged into the pulp by dilution of 1 part collector to 2 parts kerosene. The consumption of the collector violently fluctuated with the character of the ore. For Solonechnoye fluorspar it proved sufficient to use 200-250 grams per ton in the primary flotation, i.e., almost the same as the amount of oleic acid required for this ore. This study showed the dependence of recovery on pulp pH. The highest indices for recovery of fluorite in the concentrate while maintaining its satisfactory quality, and the lowest tailing losses in the rougher flotation are yielded by a pH of 8.5, i.e. with a weakly alkaline pulp. This lower alkalinity of the pulp than the optimum level for flotation with oleic acid, reduces the consumption of the fairly expensive caustic soda, which is usually employed to create an alkaline medium in fluorspar flotation.

A study of the effect of pulp temperature on flotation with carboxylic acids revealed a lower degree of dependence of the flotation indices on pulp temperature than is the case with oxidized solar oil. The quality of the concentrate remained almost unchanged throughout the entire range of temperatures studied: from 5 to 25 degrees Centigrade. The recovery however fluctuated within this temperature range, other conditions remaining the same, from 83.1 percent at pulp temperature 5 degrees to 99.5 percent at pulp temperature 25 degrees.

Sodium silicate displays a very considerable influence on

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fluorspar flotation by carboxylic acids. When its charge was increased, the quality of the concentrates was somewhat improved, i.e., quartz was depressed. However, the recovery of fluorite in the concentrate is sharply reduced at the same time, i.e. the depression of quartz is accompanied by a considerable depression of fluorite as well. The data on the influence of varying charges of sodium silicate on the flotation of Solonechnoye fluorspar by carboxylic acids from oxidized solar oil are presented in Table 39, and show a greater sensitivity of these acids to the influence of sodium silicate than is possessed by oleic acid.

Table 39

Effect of sodium silicate on the flotation of fluorspar
with carboxylic acids from naphtha

Consumption of sodium silicate in grams per ton		Yield Products in %	CaF content in %	CaF recovery in %
200	Concentrate	73.4	94.46	98.2
	Tailings	26.6	4.88	1.8
400	Concentrate	45.2	96.50	61.8
	Tailings	54.8	49.30	38.2
500	Concentrate	40.4	96.74	55.4
	Tailings	59.6	53.30	44.6
700	Concentrate	26.2	96.86	35.8
	Tailings	73.8	61.4	64.2
Flotation feed		100.0	70.7	100.0

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The charge of sodium silicate in flotation with carboxylic acids must thus be very carefully measured out.

The flotation properties of the oxy-acids were studied by charging it into the pulp in the form of their soaps, in view of the difficulty of finding a convenient solvent. Study of a number of factors showed them to be much weaker collectors for fluorspar than the carboxylic acids, the other active ingredient of oxidized solar oil. Flotation with the soap of the oxy-acids yielded concentrates with 78-92 percent CaF_2 and only low recovery; i.e., the oxy-acids are less selective than the carboxylic acids. The valuable component of oxidized solar oil is thus the carboxylic acid fraction. Freeing it of oxy-acids and unsaponifiable matter should increase the flotation properties of the product.

The naphthenic acids isolated from the wastes after treatment of petroleum with caustic alkali (acidol), were tested in the flotation of Kalangui fluorspar. The flotation activity of this product was not studied in detail. The small number of experiments made yielded results considerably inferior to those obtained with oleic acid.

The sulfonaphthenic acids obtained by the Petrov method (Petrov contact process) have good flotation characteristics for fluorspar. The IMS tested them on Solonechnoye fluorspars and obtained a finished concentrate.

The flotation properties of peat tar were studied in detail. It had been repeatedly tested as a flotation agent for

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oxidized ores, and used successfully with Khibinsk apatite. Being a very cheap agent, it was therefore studied in detail during the search for a substitute for oleic acid in fluorspar flotation. It is obtained during the coking of peat in quantities ranging from 3 percent to 8 percent, according to the coking method employed. It is composed of neutral compounds in the form of saturated and unsaturated aromatic hydrocarbons, similar to those contained in petroleum and light oil from coal tar; compounds of acid character (phenol, guaiacol, pyrocatechin, carboxylic acids); organic sulfo-compounds; pyridine bases; asphaltenes insoluble in benzene; and ether-insoluble carbonaceous residues.

Peat tars from the Magnitogorsk, URALMASH and Redkinsk plants were tested during the course of a study of peat tar as a flotation agent. The tar from the Redkinsk coking plant, which contains 10-15% benzene-insolubles, has an Engler viscosity of 2-3 degrees and a specific gravity of 0.97-0.98, gave the best results. The carboxylic acid content of the separate fractions of peat tar ranged from 4-8 percent, phenols from 4 percent to 28 percent, and bases from 4 to 12 percent.

A solvent was required in charging it into the pulp, on account of its low fluidity, and kerosene was used for this purpose.

The influence of pulp pH on flotation with peat tar was studied with Kalangui and Solonechnoye fluorspars. NaOH and HCl were used to regulate pH. Flotation with peat tar in alkaline

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media involved several disadvantages, including lowered indices and a very high persistence of the froth, impeding the further processing of the froth products.

In flotation of Solonechnoye fluorspar, in which there is good separation of fluorite from quartz, the consumption of peat tar was 960 grams per ton. The pulp was charged with sodium silicate at 300 grams per ton. The results of this series of experiments are shown in Table 40.

Table 40

Flotation of Solonechnoye fluorspar with peat tar at varying pulp pH.

Consumption in grams per ton		Pulp pH	Products	Yield	CaF ₂ content	CaF ₂ recovery
HCl	NaOH			in %	in %	in %
400	-	-	Concentrate	81.6	84.57	97.5
			Tailings	18.4	9.25	2.5
240	-	-	Concentrate	82.7	84.81	99.0
			Tailings	17.3	4.49	1.0
150	-	-	Concentrate	72.5	94.8	95.5
			Tailings	27.5	7.82	4.5
-	200	9.4	Concentrate	62.7	95.73	84.7
			Tailings	37.3	28.69	15.3
-	600	9.7	Concentrate	70.5	97.78	94.4
			Tailings	29.5	13.91	5.6
-	1000	10.1	Concentrate	72.2	96.55	98.50
			Tailings	27.8	3.50	1.50
Flotation feed				100.0	70.70	100.0

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When small amounts of acid are charged, the primary flotation yields very good separation of fluorite and quartz. Increased acid consumption reduces the selectivity of flotation. Rise of the pH of the medium past 9.7 results in a slight impairment of concentrate quality. Reduction of pulp pH favorably affects the properties of the froth.

When peat tar is used as a collector, the depression of quartz by sodium silicate is most satisfactory, and the consumption of sodium silicate is no different from that with other collectors. In a study of the optimum level of sodium silicate in flotation of Kangalui fluorspar with peat tar it was learned that addition of NaOH or HCl to the pulp gave better results for the same consumption of sodium silicate, namely 700 grams per ton.

Reduction of pulp temperature sharply lowers the efficiency of fluorspar flotation with peat tar, owing to solidification or reduced dispersion of the latter. The data of Table 41 are significant in this connection. They give the results of flotation of Solonechnoye fluorspar at varying pulp temperature. The consumption of agents, in grams per ton, was: NaOH, 600; sodium silicate, 300; tar, 960.

[See next page for Table 41]

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Table 41

Flotation with peat tar at varying pulp temperature

Pulp temperature		Yield	CaF ₂ content	CaF ₂ recovery
in degrees				
Centigrade	Products	in %	in %	in %
5	Concentrate	11.6	-	-
	Tailings	86.4	-	-
10	Concentrate	45.0	97.90	63.6
	Tailings	55.0	40.85	36.4
20	Concentrate	71.5	94.70	96.0
	Tailings	28.5	9.85	4.0
25	Concentrate	73.0	96.42	99.6
	Tailings	27.0	13.00	0.4
Flotation feed		100.0	70.7	100.0

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The influence of temperature on mineralization of the froth is interesting in flotation with peat tar. With rising temperature the mineralization of the froth increased from 36.5 percent at 5 degrees to 46.5 percent at 25 degrees. In general mineralization of the froth is higher in fluorspar flotation with peat tar than with other collectors (carboxylic acids, oxidized solar oil, oleic acid).

A good dispersion of peat tar throughout the pulp is extremely important in flotation with it. To assure this, it must be introduced into the flotation machine mixed with kerosene or some other solvent. It does not dissolve entirely, but undergoes a considerable degree of liquefaction and becomes thin and fluid as a result of this mixing. Increasing the concentration of the tar in such a "solution" reduces its dispersion and unfavorably affects the flotation results, especially the recovery.

The cleaning flotations with peat tar are entirely satisfactory. In concentrating Kalangui fluorspar according to the normal routing, used with oleic acid and consisting of one rougher and two cleaner flotations, a finished concentrate with over 95 percent fluorite content is obtained. The results of one of these experiments, with processing the middlings, are shown in Table 42.

[See next page for Table 42]

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Table 42

Flotation of Kalangui fluorspar with peat tar

Consumption of		Yield	CaF ₂ content	CaF ₂ recovery
Agents in	Products	in %	in %	in %
grams per ton				
Rougher flotation				
sodium silicate				
700	Concentrate	43.3	95.39	63.85
HCl 135	Middlings	30.1	58.40	27.23
Peat tar 2000				
Pulp density =				
1:3.5				
First cleaner	Tailings	26.6	21.60	8.92
flotation:				
Sodium silicate				
300				
Second cleaner				
flotation without				
agents	Flotation feed	100.0	64.69	100.0

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With Solonechnoye fluorspar the results were better, and in no way inferior to those obtained with other agents. Table 43 shows the results of a few of these experiments.

Table 43

Flotation of Solonechnoye fluorspar with peat tar.

Collectors	Product	Yield in %	CaF ₂ content in %	CaF ₂ recovery in %
580 grams per ton of 1:2 tar in turpentine	Concentrate	67.8	97.92	93.9
	Tailings	32.2	13.35	6.1
960 grams per ton of 1:2 tar in kerosene	Concentrate	72.2	97.24	99.2
	Tailings	27.8	1.8	0.8
Flotation feed		100.0	70.7	100.0

The flotation properties of the separate distillation fractions of peat tar were studied to learn which part possesses the highest flotation activity. Fraction I passed over up to 200 degrees, II up to 225 degrees, III up to 275 degrees, and IV up to 300 degrees. [Presumably the lower limit of each fraction is the upper limit of the preceding fraction, as usual; i.e. these fractions are not meant to be cumulative.] The first fraction, in an alkaline medium, hardly floats fluorspar at all. On acidifying with HCl flotation takes place, but yields

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only a small amount of concentrate. At pH = 6.3 the results were better: 95.9 percent fluorite in the concentrate, with 67.8 percent recovery.

The flotation properties of the second fraction were somewhat better, and an almost neutral medium proved optimum for it. The third fraction gives normal extraction on charging with small amounts of acid. Flotation in an alkaline medium is unsatisfactory. The fourth fraction gives good results for flotations in an alkaline medium, although recovery remains higher, for this fraction as well, in a weakly acidified pulp.

Figure 19. Flotation of fluorspar with agent IMS-211 and charges of NaOH and HCl. Bottom axis: HCl grams per ton NaOH grams per ton

In the experiments with varying pH of the medium, none of the fractions gave results with Solonechnoye fluorspar better than those with untreated peat tar (containing all fractions) or even as good as those results. Complete tar is thus more active in flotation than any of its separate distillation fractions up to 300 degrees.

Besides the agents above described for fluorspar flotation, the following complex (compounded or synthetic) agents were also tested, with good results: IMS-211, developed by the IMS (Eigheles), and Agents Nos 2 and 3, developed by the Vaychag Laboratory of the GLAVSEVMORPUT' (Gal'perin).

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Agent IMS-211 is a mobile liquid that can readily be charged into the pulp. The influence of pulp pH on fluorspar flotation with this agent was studied on a number of ores. The most favorable froth characteristics and flotation indices were obtained in weakly alkaline media. Figure 19 shows the results of Kalangui fluorspar flotation with this agent.

In view of the large consumption of sodium silicate in flotation of Kalangui fluorspar, leading to alkalinization of the pulp, the best results are achieved by charging the pulp with small quantities of HCl (200 grams per ton).

In flotation of Takob fluorspar, a pulp pH of 8.3 to 8.4 gave the best results. This also required charging small amounts of acid after the alkaline flotation of the lead minerals. It should be noted that flotation with Agent IMS-211 is also satisfactory in alkaline media.

When this agent is used, the depression of quartz is produced as usual by sodium silicate, which with this collector is ordinarily used in small amounts and in any case is not needed in amounts any different from those required when other well-known collectors are employed.

As with the other agents, pulp temperature has a marked effect on the flotation activity of Agent IMS-211, and temperatures under 14 degrees make flotation results considerably worse.

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Figure 20. Relation between CaF_2 content of concentrate and CaF_2 recovery in it, for different collectors.

1: oleic acid

2: Agent IMS-211

The mineralization of the froth, which was studied in flotation of Takob fluorspar, is the same with this agent as with oleic acid, but its persistence is lower than with oleic acid, which fact facilitates treatment of the froth-products at concentration mills.

Table-44 shows the comparative data obtained after detailed selection of optimum conditions for Kalangui fluorspar flotation with various agents (without processing the middlings.)

These data show Agent IMS-211 to be distinguished by good flotation characteristics. It is both cheap and not in short supply, and should therefore find application in the flotation of fluorspar ores.

These conclusions were entirely confirmed after careful comparative studies of the flotation properties of oleic acid and Agent IMS-211, made on Takob ores. Curves 1 and 2 in Figure 20 show the dependence between concentrate quality and fluorite recovery for both agents. Curve 1, for oleic acid, which like the other curve is linear, is steeper. Thus with improving quality of the finished concentrate the recovery is higher with the Agent than with oleic acid.

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The grade of the concentrates obtained from flotation with Agent IMS-211 depends on the properties of the ore and may be very high. The CaF_2 content of the concentrate from Kalangui spar is 95-96 percent, while concentrates with 97.1 percent, 97.9 percent and even 99.4 percent CaF_2 have been obtained from Takob spar, and for Solonechnoye spars it was 98.46 percent.

Table 44

Flotation of Kalangui fluorspar with various agents

Consumption of

agents in			Yield	CaF ₂ content	CaF ₂ recovery
grams per ton	Collectors	Products	in %	in %	in %
(1)	(2)	(3)	(4)	(5)	(6)
Sodium silicate	Oleic acid	Concentrate	37.73	97.95	56.9
1000		Middlings	34.97	70.06	37.9
NaOH 730		Tailings	27.30	12.30	5.2
		Flotation feed	100.0	65.0	100.0
Sodium silicate 750	Oxidized	Concentrate	49.0	96.86	70.9
NaOH 1400	paraffin	Middlings	19.6	69.0	19.9
Pine oil 20		Tailings	31.4	18.83	9.2
		Flotation feed	100.0	65.0	100.0
Sodium silicate 750	Carboxylic	Concentrate	48.8	96.08	72.5
NaOH 1400	acids from	Middlings	22.8	60.00	20.4
Pine oil 20	paraffin	Tailings	28.4	15.55	7.1
		Flotation feed	100.0	64.6	100.0

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(1)	(2)	(3)	(4)	(5)	(6)
Sodium silicate 700	Oxidized	Concentrate	48.5	95.53	71.75
HCl	220 naphtha	Middlings	25.0	56.10	21.8
	oil	Tailings	26.5	16.22	6.7
		Flotation feed	100.0	64.69	100.0
Sodium silicate 1000	Peat tar	Concentrate	43.3	95.39	63.85
HCl	135	Middlings	30.1	58.4	27.23
		Tailings	26.5	21.6	8.92
		Flotation feed	100.0	64.69	100.0
Sodium silicate 700	Agent	Concentrate	49.0	95.45	72.10
HCl	135 IMS-211	Middlings	27.92	55.85	24.18
		Tailings	23.1	10.42	3.72
		Flotation feed	100.0	64.69	100.0

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Compounded Agents No 2 and 3 of the Vaychag Laboratory (Gal'perin) were tested on Amdermin ores and gave higher indices than oleic acid. A quartz variety of Amdermin fluorspar with 46.0 percent CaF_2 yielded, with Agent No 2, after one rougher and three cleaner flotations, a concentrate with 98.6 percent CaF_2 . A carbonate variety of Amdermin fluorspar with 47.5 percent CaF_2 and 19.1 percent CaCO_3 , yielded a concentrate with 97.5 percent CaF_2 . More detailed data on the flotation of Amdermin fluorspar is presented below.

Thus as a result of detailed research the possibility of using a number of new collectors instead of oleic acid has been established, and the conditions for their use have been determined. Some of them possess appreciable advantages over oleic acid.

THE CONCENTRATION OF FLUORSPAR ORES OF THE VARIOUS DEPOSITS

CONCENTRATION OF FLUORSPAR FROM THE SOLONECHNOYE DEPOSIT

The Solonechnoye deposit is located in Gazimurozavodskiy Rayon of the East Siberian Kray, and is one of the richest fluorite deposits of very high quality. The massive crystalline layers of fluorspar are traversed by quartz in fine networks or in fairly substantial streaks. The peculiar genesis of the deposit, namely the different times at which the quartz and fluorite were crystallized out, is responsible for the good separation of the components of the ore, and its concentration gives most satisfactory

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results [25]. The principal ore-body is composed of fluorspar, the content of which fluctuates between 70 and 85 percent throughout the deposit.

Samples of Solonechnoye fluorspar tested by the IMS for amenability to concentration contained 81.74 percent and 74.8 percent of CaF_2 [32].

In these tests great attention was paid to the prospects of obtaining concentrates of lump and gravel grade. The coarse dissemination of the associated mineral made it seem likely that high-grade lump and gravel concentrates could be obtained by hand picking and jigwork. Quartz is the principal admixture in Solonechnoye ores, and high quartz content is objectionable in both metallurgical and acid grades of fluorspar. The aim of concentration was therefore to secure a concentrate with high CaF_2 content. The substantial distances between the deposit and the railroad and the consuming centers rendered it economically expedient to prepare high-grade products from these ores.

Hand Picking

The amenability of Solonechnoye fluorspars to concentration by handpicking was studied on the first and second samples. Hand picking separated a high-grade concentrate with about 95 percent fluorite and spent rock with a very low fluorite content (of about 20 percent). At the same time the amount of second-grade concentrate that could be produced was also studied. The ore coarser than 20-25 millimeters was first screened to remove the

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finer, and then subjected to hand picking. The results of a number of experiments in hand picking of these ores are shown by Table 5 (page 214). Depending on the care with which picking was done, 15 to 19 percent of a concentrate with fluorite content of 95-96 percent were obtained. Hand picking of a poorer fluorite sample yielded 18.4 percent of Type I concentrate, but there was no Type II.

Jigwork

The ore remaining after the separation of the Type I concentrate and the waste tailings was concentrated by jigwork, for which purpose it was crushed to 13 millimeter size, and prepared for jigging by screening into the following sizes: 13-10 millimeter; 10-6.5 millimeter; 6.5-4 millimeter; 4-3 millimeter; 3-2 millimeter; and 2 millimeter. The presence of a considerable amount of concretions in the 13-10 millimeter class made its jigging unsatisfactory. The first concentrate from this class contained 82.0 percent fluorite, and by rejigging it a concentrate with 95.9 percent CaF_2 could be obtained. On account of the concretions, however, the recovery was low. The normal crushing size jigwork for concentration of the ore of the sample under study proved to be 10 millimeters. The granulometric characteristics of the Solonechnoye ore, crushed to 10 millimeters, is given in Table 45.

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Table 45

Screening of 10 mm. fluorspar before jigging.

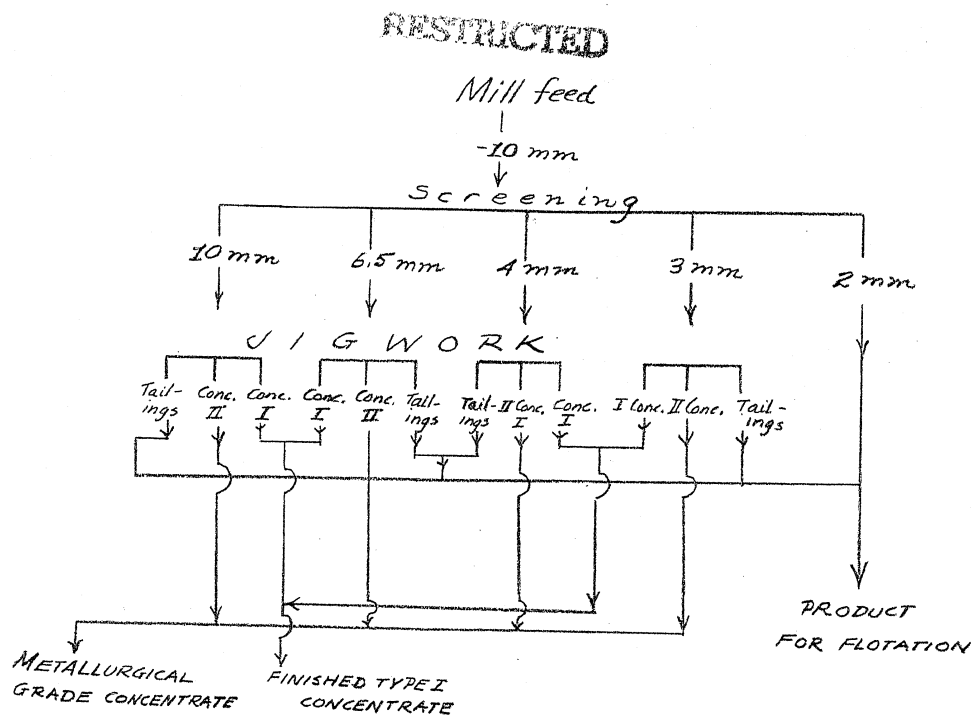
Classes in mm.	Yield in %	CaF ₂ content in %	CaF ₂ Recovery in %
-10 + 6.5	32.60	73.52	30.00
-6.5 + 4	13.94	78.14	13.63
-4 + 3	6.50	79.20	6.44
-3 + 2	19.11	83.66	20.50
-2	27.85	84.46	29.43
Screen Feed	100.00	79.75	100.00

Figure 21 is the flow-sheet of the jigwork. A Harz-type 3-cell laboratory jig was used in the tests. The jigwork envisaged obtaining a high-grade type I concentrate with about 95 percent fluorite, and then a type II concentrate suitable for metallurgical use.

Figure 21. Flow-sheet of jigwork on Solonechnoye fluorspar.

[See next page]

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The middlings and tailings from the jigwork, combined with theunjigged class under 2 millimeters, made up the so-called flotation ore.

Table 46 gives the results of the tests of the amenability to concentration by jigwork of fluorspar of the size-classes from 13 to 2 millimeters. The productivity of the jig ranged from 600 to 370 kilograms per hour per square meter of jigging surface.

In view of the poor amenability to concentration, the concentrate from the first jigging of the 13-10 millimeter class was rejigged, and Table 46 shows the results, including that second or cleaner jigging. The jigwork products of the different classes, which products contain about 95 percent CaF_2 , are combined into the Type I concentrate. The jigwork products with fluorite content from 81.4 to 93.9 percent are combined into Type II concentrate. The products with less than 80 percent CaF_2 are combined into the ore

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for flotation. The data of Table 46 show that rougher jigging of the classes finer than 10 millimeters results in recovery into the Type I concentrate of about 55 percent (46.4 to 62 percent) of the fluorspar in each class. The grade of the concentrates from jigging the coarser classes is lower than from the finer classes. The recovery of the cleaner jigging is sharply lower. The total yield in Type I concentrate from jigging of the classes from 13 to 2 millimeters was 21.7 percent of the jig feed, with mean fluorite content of 95.8 percent; of Type II concentrate it was 25 percent of jig feed, with mean fluorite content of 89.8 percent.

[See next page for Table 46]

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Table 46

Jigging Solonechnoye fluorspar
(under 13 mm. in size)

Size-Class of ore in mm.	Products	Yield in Percent		CaF ₂ Content in %	CaF ₂ Recovery in Percent	
		of amount used in experiment	of original amount		of amount used in experiment	of original amount
(1)	(2)	(3)	(4)	(5)	(6)	(7)
13 - 10	Concentrate	27.20	6.81	95.90	34.60	
	Middlings)	72.80	18.21	67.60	65.40	
	Tailings)					
10 - 6.5	Concentrate I	55.20	8.54	91.60	64.60	
	Middlings)	44.80	6.96	61.94	35.40	
	Tailings)					
6.5 - 4	Concentrate I	56.20	2.14	95.15	62.00	
	Concentrate II	28.00	1.07	82.00	28.60	
	Tailings	15.80	0.60	61.01	09.40	

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(1)	(2)	(3)	(4)	(5)	(6)	(7)
4 - 3	Concentrate I	40.90	3.19	93.90	46.40	
	Concentrate II	46.60	3.64	81.40	45.70	
	Tailings	12.50	0.96	52.68	7.90	
3 - 2	Concentrate I	49.70	4.18	95.00	54.54	
	Concentrate II	40.80	3.42	85.86	40.46	
	Tailings	9.750	0.80	45.59	5.00	
13 - 2	Concentrate I	21.7	13.13	95.8	26.6	15.3
	Concentrate II	25.0	15.15	89.8	28.8	16.6
	Flotation ore	53.3	32.24	65.4	44.6	25.7
		-	60.52	79.89	100.0	57.6

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The following results of the concentration of the lump and granular material of Sample I, with 81.74% CaF_2 , are obtained by adding the products of the jigwork to those of the hand picking, and are shown in Table 47.

Table 47

Jigging of lump and granular fluorspar of the Solonechnoye deposit

Products	Size of Pieces or granules	Yield in %	CaF_2 content in %	CaF_2 recovery in %
Concentrate I	lump	19.4	94.94	22.4
Concentrate I	gravel	13.1	95.8	15.3
Concentrate II	gravel	15.1	89.8	16.6
Flotation ore	under 2 mm.	49.7	73.8	44.9
Tailings from hand picking	lump	2.7	18.43	0.3
Jig feed	under 100mm.	100.0	81.74	100.0

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Fluorspar of 81.74 percent CaF_2 content thus yielded, on hand picking and jigging, 32.5 percent of Type I concentrate, with 95.0 to 95.8 percent CaF_2 , together with 15.1 percent of a concentrate with 89.9 percent CaF_2 . The total recovery of fluorite into both concentrates amounted to 54.3 percent.

Judging by the preliminary experimental data, the routine could be simplified. This is being checked at present.

Tabling

The amenability of the fines under 2 millimeters to tabling concentration was tested on a Wilfley laboratory table.

The preliminary experiments showed that separation on the table, accompanied by formation of a fan of products, commences only at classes finer than 35 mesh.

By tabling fluorspar crushed to pass a 35 mesh screen a type II concentrate with 84.9-93.8 percent fluorite was obtained, with recovery from 56.6 to 68.7 percent. These results are far inferior to those of flotation, which is the most efficient method of concentrating fluorspar.

Flotation

The flotation of Solonechnoye fluorspar was studied on two samples, one of them a sample of original ore with 81.74 percent CaF_2 , and the other the sample of flotation ore separated after removal of the lump and granular concentrate from the ore. The latter sample contained 72.7 percent of fluorite. The study of

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the amenability of the original ore sample to concentration by flotation yielded the indices necessary for working out the optimum conditions for the flotation of the poorer ores. ¶ Figure 22 (page 262) Influence of pulp pH on the flotation of Solonechnoye fluorspar.

The optimum fineness of grind for fluorspar with 81.74 percent CaF_2 was studied in a series of flotation experiments in a Ruth sub-aeration flotation machine on fluorspar ground to varying fineness.

A grind with 43 percent of the ore particles passing a 200 mesh screen proved to be optimum. At this fineness the tailings loss in flotation is at a minimum, amounting to 6.2 percent under the conditions of the experiment. Finer grinding than this sharply increases tailings losses under the same flotation conditions.

The flotation of fluorspar with oleic acid is optimum in an alkaline medium with pH close to 10. The determination of the optimum pulp pH in flotation of Solonechnoye fluorspars was made in the course of a series of flotation experiments with varying charges of NaOH, and gave the results which are shown by Figure 22.

The conditions of this series of experiments were: pulp density, 1:4; pulp temperature, 23 degrees; consumption of agents: sodium silicate, 300 grams per ton, oleic acid, 300 grams per ton; pine oil, 30 grams per ton. The flotation of Solonechnoye fluorspar

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with oleic acid yield, the highest grade concentrate and the highest recovery at a pulp pH of 9.1 to 9.2. The tailings losses in the best experiments ranged between 7.8 percent and 6.1 percent. These conclusions were confirmed by checks.

In the determination of optimum pulp pH for the flotation of the jigwork tailings, this was not found to differ from the value established for the flotation of original ore.

In flotation of Solonechnoye fluorspar, the quartz is depressed by charging sodium silicate into the pulp, as is always done. The necessary amount was found by a number of experiments to be 200 grams per ton.

The consumption of this depressor increases to 300 grams per ton in the flotation of fines and jigwork tailings, which are poorer in fluorite and contain somewhat more quartz.

Pine oil was used as a frothing agent. To verify the need for ^{its use} and check the accuracy of the established norms for its consumption, ~~however~~ a series of experiments was run using varying amounts of it.

It developed that pine oil exerts a powerful influence on the course of flotation with oleic acid. The most satisfactory results were obtained by using 60 grams per ton, when the yield of concentrate was 82.73 percent, with CaF_2 content of 92.95 percent and recovery of 94 percent. The tailings loss was 6 percent. When flotation was done without pine oil, there

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was a very slight improvement in the grade of the concentrate, but recovery fell to 77.1 percent.

Cleaner Flotations

A single rougher flotation, using oleic acid as a collector, does not yield a finished concentrate even under optimum conditions.

Completely finished concentrates were obtained after a cleaner flotation. The results of a typical experiment are presented in Table 48.

[See next page for Table 48]

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Table 48
Flotation of Solonechnoye fluorspar

Operation	Consumption of Agents		Products	Yield in %	CaF ₂ Content in %	CaF ₂ Recovery in %
	in grams per ton					
(1)	(2)	(3)	(4)	(5)	(6)	
Rougher flotation	NaOH	300	Concentrate I	73.5	91.26	93.00
	Sodium silicate	300	Middlings I	1.1	80.62	1.24
	Oleic acid	300				
	Pine oil	75	Tailings	25.4	16.37	5.76

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(1)	(2)	(3)	(4)	(5)	(6)
Cleaner flotation					
	Sodium silicate 300	Concentrate II	67.5	97.26	90.00
	Oleic acid 130				
	Pine oil 60	Middlings II	6.0	39.98	3.00
		Concentrate	67.5	97.26	90.00
		Total middlings at end of experiment	7.1	47.10	4.24
		Tailings	25.4	16.37	5.76
		Flotation feed	100.0	72.04	100.00

Net results of
the experiment
at pH = 9.7

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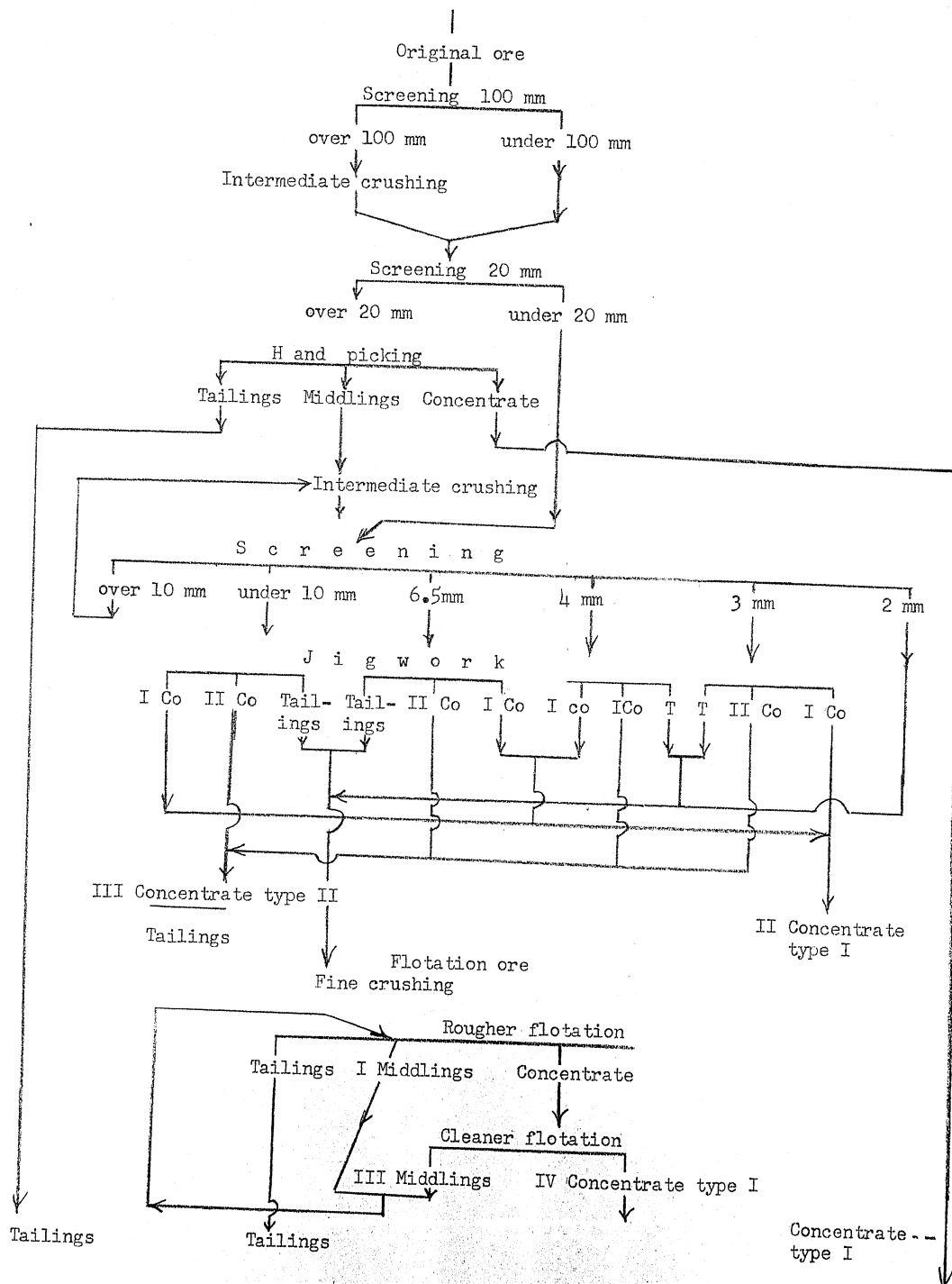
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A concentrate with 97 percent CaF_2 was obtained from flotation of the original ore, containing 81.74 percent CaF_2 and likewise from flotation of the jig tailings containing 73 percent CaF_2 . The recovery of fluorite in the concentrate, without processing the middlings, ran from 82 to 90 percent. In both of these cases, the optimum flotation conditions were as follows: the necessary pulp pH is 10.2 to 9.7, attained by charging the pulp with NaOH. Consumption of sodium silicate in the rougher flotation is 200 grams per ton for the original ore, and 300 grams per ton for the jig tailings. The oleic acid consumption in the rougher flotation is 300 grams per ton, while that of pine oil is 75 grams per ton. In the cleaner flotation oleic acid consumption is 130-150 grams per ton; that of pine oil is 60-75 grams per ton. An additional charge of sodium silicate at the rate of 300 grams per ton is charged in the cleaner flotation of the jig tailings.

Based on the experimental studies of the conditions and results of the concentration of Solonechnoye fluorspar containing about 82 percent of fluorite; the following routing for the concentration of this ore may be noted, as shown in Fig 23.

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After separation of the fines (under 20 millimeters) the ore is hand picked and a type I lump concentrate, with 95 percent fluorite content, is removed, together with the waste tailings. The impoverished ore is then crushed to 10 millimeters and screened into a number of classes. The classes coarser than 2 millimeters are separately jigged, yielding a type I gravel concentrate with 95 percent fluorite, a type II concentrate with 90% fluorite, and tailings. The latter, together with the fines (fluorspar finer than 2 millimeters) form the "flotation" ore to be concentrated by flotation.

The flotation ore is ground so that 43 percent of the particles will pass a 200 mesh screen and is given a rougher and a cleaner flotation, yielding a type I concentrate, with 97 percent fluorite, and waste tailings. The total recovery in the concentrate is 94.7 percent.

A general summary of the data, for recapitulation and orientation, on concentration of fluorspar with 81.74 percent fluorite, according to this routing, is given in Table 49.

Flotation may be used alone to concentrate this ore. In this case a concentrate in powder form is obtained, which contains about 97 percent of fluorite. The very considerable industrial demand for the lump and gravel grades of fluorspar, however, makes it reasonable to consider the routing above set forth to be a more rational method of concentrating the Solonechnoye fluorspars.

According to the latest exploration data, the mean fluorite

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content of Solonechnoye ores is lower than in the samples studied. In connection with this the concentration indices above set forth are currently being reviewed and elaborated.

Table 49
Concentration of Solonechnoye fluorspars

Products	State of Aggregation	Method of Concentrations	Yield in %	CaF ₂ Content in %	CaF ₂ Recovery in %
Concentrate I	Lump	Hand picking	19.4	94.94	22.4
Concentrate II	Gravel	Jigging	13.1	95.8	15.3
Concentrate III	Gravel	Jigging	15.1	89.8	16.6
Concentrate IV	Powder	Flotation	33.5	97.26	40.4
Tailings I	Lump	Hand picking	2.7	18.43	0.8
Tailings II	Powder	Flotation	16.2	22.2	4.5
Concentrate			82.6	89.80-97.26	94.7
Tailings			17.4	18.43-22.2	5.3
Mill feed			100.0	81.74	100.0

CONCENTRATION OF FLUORSPARS FROM THE KALANGUI AND ABAGAITUI
DEPOSITS

The amenability of Kalangui fluorspars to concentration has been studied by the Institute of Economic Mineralogy and the GINTSVETMET. Investigations were conducted on 4 ore samples,

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which were taken: I: from the shafts, consisting of run-of-the-mine ore; II: from prospecting pits after hand-picking; III: from 64 points of the deposit; IV: from a number of points representing the places richest in quartz in the deposit /11,23,31/.

The Kalangui samples, which differ somewhat among themselves as to aggregation and chemical composition, consist on the whole of large and small lumps of macrocrystalline fluorspar with inclusions in the form of streaks and larger formations of quartz, and with small adhesions of clay, together with lumps of breccia, the debris of which is cemented with microcrystalline quartz, fluorspar and clay. The amount of clay in the samples fluctuates between 6 and 9 percent, while calcite holds between the limits of 1 to 2 percent. Sulfides in the form of pyrite and chalcopyrite are disseminated in small amounts in the samples from the deeper parts of the deposits.

Each of the four Kalangui samples was tested separately. The results of these tests were fairly close together and admit of certain definite conclusions with respect to the amenability to concentration of the fluorspar ores, which are typical for the whole group of deposits located in the general vicinity of Kalangui.

Table 50 gives the chemical analysis of all the samples under study.

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Table 50

CHEMICAL ANALYSIS OF THE SAMPLES

Name of Compound	Content in Percent			
	Sample No 1	Sample No 2	Sample No 3	Sample No 4
CaF ₂	69.74	64.96	76.68	64.69
SiO ₂	23.06	26.51	-	25.64
Al ₂ O ₃	2.06	3.35	-	5.97
Fe ₂ O ₃	0.80	1.07	-	0.20
FeO	0.41	0.86	-	-
CaO	1.18	1.07	-	-
MgO	traces	traces	-	-
Ba	none	none	-	-
CO ₂	1.36	1.12	-	-
S	0.44	0.55	-	-
P	0.12	0.20	-	-
W	none	none	-	-

The high fluorite content of the ore and the very considerable number of lumps of fairly pure fluorspar in it made it possible to secure a certain amount of concentrate meeting the technical requirements of metallurgy by simple hand picking.

Samples 1 and 2 were classified for size-groups.

The product coarser than 75 millimeters was sorted out on the picking table into concentrate and impoverished product.

The results of hand picking the product over 75 millimeters and of the classification, are shown in Table 51.

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Table 51

CHEMICAL ANALYSIS OF THE SAMPLES

<i>Sample No 1</i>			
Products	Yield in %	CaF ₂ Content in %	CaF ₂ Recovery in %
Hand Concentrate	30.00	93.26	39.28
Impoverished product	19.20	44.26	12.04
75-25 mm class	26.47	72.62	37.20
Class under 25 mm.	14.33	57.03	11.48
Original ore	100.00	71.21	100.00

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The results of the hand-picking with respect to yield and grade of concentrate are very close to the data in existence on hand sorting at the Kalangui mine.

The high percentage of fines in the picked rock, as well as the presence of fluorite in the breccia cementation, make it impossible to obtain tailings of waste quality after the picking, or to achieve any substantial increase in the yield of hand concentrate. The recovery through hand-picking alone thus remains very low (about 40 percent), and hand-picking can thus represent only a single stage of the concentration, which under all conditions imperatively demands the subsequent and further concentration of its residues by other and more efficient methods.

Of these other methods, tabling and flotation were tested during the years 1929, 1931, and 1934.

The results of tabling have already been presented in Tables 10 and 11. Under the best conditions (when the products of screening were concentrated) the CaF_2 content of the concentrate did not exceed 92.69 percent. The effort to secure pure concentrates (with only insignificant amounts of concretions) resulted in a high yield of middlings, and the tailings losses were abnormally high.

It should, of course, be noted that concentration of the products of hydraulic classification did yield a concentrate with 95.0 percent of CaF_2 ; but both yield and recovery of the concentrate were obviously unsatisfactory.

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The experiments conducted with wet concentration on tables confirm the fact that tabling cannot play an independent role in the routing of Kalangui fluorspar concentration. It is entirely clear that tabling can neither give high recovery nor, what is most essential of all, can it get all the fluorite out of the tailings.

Flotation

The amenability of Kalangui fluorspar to concentration by flotation was studied on all four samples.

According to the data of mineralogical researches, the fineness of grind necessary to assure the separation of fluorspar from its associated minerals fluctuates between 60 and 100 mesh. The preliminary flotation experiments with samples 1 and 2 gave the best results, both in quality of concentrate and in recovery, with a 100 mesh grind. This stage of subdivision of the product is suitable for those industries that require a high-grade spar for the production of cryolite and sodium fluoride. A finer grind gave less favorable results.

A detailed test of the optimum fineness of grind was made by the Institute of Economic Mineralogy and showed that the best grind for flotation contains 69.1 percent, or roughly 70 percent of particles that pass a 200 mesh screen, with 97.3 percent passing a 100 mesh screen. This confirms and clarifies the preliminary conclusions.

In flotation with oleic acid the pulp is charged with caustic soda to bring the pH up to about 11. The consumption

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of sodium silicate in the rougher flotation is from 100 to 200 grams per ton. Before the flotation of fluorspar the sulfides are taken out by the usual agents.

After studying the conditions of the cleaner flotations and the results of the entire flotation process for samples 1 and 2, the routing shown in Fig 24 was proposed.

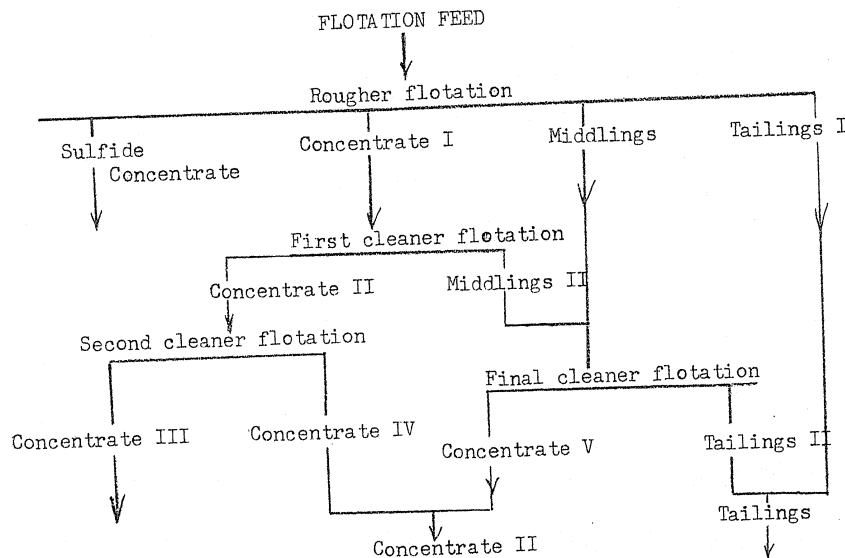


Fig 24. Flow-sheet for Kalangui fluorspar

The results of flotation by the routing in Fig 24 for samples 1 and 2 of Kalangui fluorspar are given in Table 52.

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Table 52
Flotation Of Kalangui Fluorspars

Consumption of		Sample No	Products	Yield in %	CaF ₂ Content in %	CaF ₂ Recovery in %
Agents in	Grams per ton					
(1)	(2)	(3)	(4)	(5)	(6)	
Oleic Acid	500	1	Sulfide Product	2.31	54.1	1.9
Sodium Silicate	1000		Type I Concentrate	35.71	97.82	52.20
Pine Oil	30		Type II Concentrate	19.94	89.84	26.69
NaOH	730		Tailings I	35.71	30.94	16.5
			Tailings II	6.33	26.50	2.8
Mill Feed				100.0	66.95	100.0

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(1)	(2)	(3)	(4)	(5)	(6)
	2	Sulfide Product	4.08	55.46	3.8
		Type I Concentrate	37.73	97.95	56.9
		Type II Concentrate	21.21	89.92	29.1
		Tailings I	27.30	12.30	5.2
		Tailings II	9.70	35.10	5.2
		Mill Feed	100.0	65.0	100.0

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Pine oil is added at the very beginning of flotation, after which the sulfide concentrate is taken out. The agents are added in two portions during the cleaner flotation: after the first, concentrate I is taken off, while Middlings I is taken off after the second. Agents are also added during the recleaner flotation. The middlings are recleaned separately since they contain considerable argillaceous admixture.

It must be admitted that this flotation routing is not entirely satisfactory; it yields a considerable amount of Type II concentrate besides the finished concentrate.

As a result of this stage of the tests of Kalangui fluorspar, the following concentration routing has been proposed for it: about 23 percent of a lump spar of grade not lower than 85 percent CaF_2 is first separated with about 30 percent recovery from the run-of-the-mine mill feed. A portion of this concentrate is distinguished by cleanness and whiteness and can be picked for ceramic grade spar. This portion is jigged after crushing to 40 millimeters, bringing its fluorite content up to 95 percent. The remaining ore is ground and treated by flotation according to the above-described routing.

The yield of the various products from processing run-of-the-mine ore by this routing is shown in Table 52.

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Table 53

Products	Yield	CaF ₂ Content	CaF ₂ Recovery
	In %	In %	In %
Metallurgical Concentrate	12.1	87.0	15.0
Ceramic Concentrate	11.0	95.0	15.0
Cryolite Concentrate	23.6	98.0	33.0
Type II Concentrate	17.1	90.0	22.0
Sulfide Product	3.2	55.0	2.5
Tailings	33.1	26.5	12.5
Mill Feed	100.0	70.0	100.0

The production of a Type II concentrate is one serious defect shown by these results. Another is the high fluorite content of the exhausted tailings. The experiments on recleaning these tailings with oleic acid did not work out very well, using a very large quantity of agents and yielding a concentrate very badly contaminated with quartz and argillaceous material.

To elucidate the influence of the presence of argillaceous silts in the products yielded by fine crushing of Kalangui fluorspars,

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supplementary desliming experiments were run on the finely divided ore in the presence of caustic soda.

Preliminary separation of the silts rich in argillaceous admixtures reduces the consumption of the collector and makes the process more uniform, yielding poorer tailings, but results at the same time in substantial slime losses. Thus there is no net reduction of overall losses.

Flotation of sample 4 with agent IMS-211 showed that it was possible to secure only a single type I concentrate with over 95 percent CaF_2 and to reduce tailings losses at the same time. The details of this study, conducted during the investigation of the new fluorspar flotation agents, have been already presented above. The following conditions were consequently recommended for the flotation of Kalangui fluorspars:

Grind: 70 percent to pass 200 mesh

Consumption of agents during rougher flotation:

Sodium silicate: 700 grams per ton

Agent IMS-211: 1400 grams per ton

HCl: 135 grams per ton

Sodium silicate at the rate of 340 grams per ton is charged in each of the first and second cleaner flotations. Flotation under these conditions, by the routing shown in Fig 25, without processing the middlings, yielded the results set forth in Table 54.

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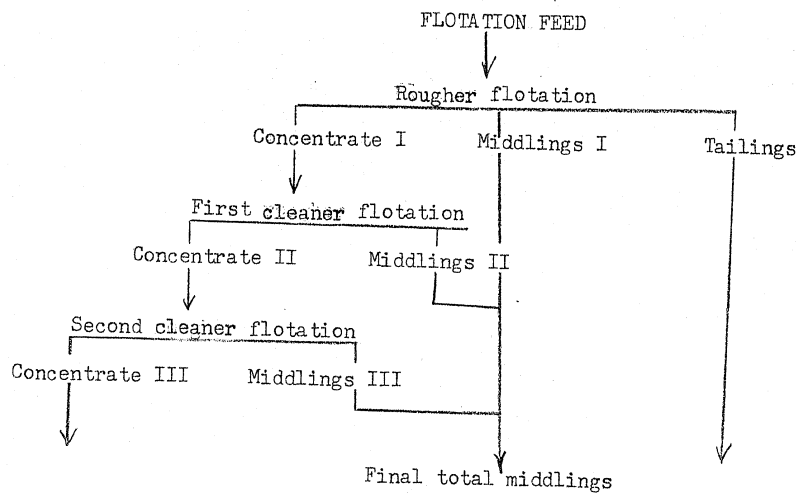
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Fig 25. Flow-Sheet For Flotation of Kalangui Fluorspars

Table 54

FLOTATION OF KALANGUI FLUORSPAR WITH AGENT IMS-211

Products	Yield in %	CaF ₂ Content in %	CaF ₂ Recovery in %
Concentrate	50.0	95.08	77.00
Middlings	32.67	46.1	23.3
Tailings	17.33	10.23	2.7
Flotation Feed	100.0	64.69	100.0

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Other experiments with the same reagent yielded concentrates with higher fluorite content -- 96.27 percent etc.

The amenability of Kalangui fluorspar to jigwork concentration is presently being studied. The VIMS is now working out a concentration routing for Kalangui ore that includes hand-picking, jigging and flotation.

The concentration of fluorspar from the Abagaitui deposit was studied on a single sample with 72.43 percent CaF_2 .

The sample consisted of fine lumps of size not over 40 millimeters. Its amenability to concentration was tested by tabling and flotation.

Tabling gave unsatisfactory results and can at best play an auxiliary role in the concentration routing.

The results of the Kalangui tests were taken into consideration in testing the amenability of the Abagaitui fluorspar to concentration by flotation. The grind adopted was the same as that for the Kalangui samples, namely 100 mesh.

The results of the flotation of Abagaitui fluorspar are shown in Table 55.

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Table 55

FLOTATION OF ABAGAITUI FLUORSPAR

Products	Yield in %	CaF ₂ Content in %	CaF ₂ Recovery in %
Type I Concentrate	59.29	97.7	80.77
Type II Concentrate	8.81	77.25	9.49
Tailings	31.90	21.9	9.74
Flotation Feed	100.0	72.43	100.0

As may be seen from Table 55, flotation yielded entirely satisfactory results, giving a high-grade fluorspar concentrate. All the tailings losses were very low. The type II concentrate however, is only of middlings grade under present technological conditions and requires further processing to convert it into a finished concentrate.

The entire possibility of concentrating the Abagaitui fluorspars was demonstrated by the investigation. It should be taken into account that the character of the ore taken from the workings admits of the inclusion of hand-picking in the concentration routine.

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CONCENTRATION OF FLUORSPARS FROM THE AURAKHMAT DEPOSIT

Three ore-samples were used in the study of the concentration of Aurakhmat fluorspar. The first sample consisted of pure fluorite. The second sample consisted of 8 partial samples of Aurakhmat ore and was characteristic of the central portion of the deposit, where thickness is greatest. The third sample characterized a number of sections of the deposit. The chemical analysis of the samples is given in Table 56.

TABLE 56

Chemical Analysis of Three Samples of Fluorspar

Content in Percent								
Sample								
No.	CaF ₂	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃ +FeO	CaO	BaO	CO ₂	SO ₃
1	96.9	-	-	-	-	-	-	-
2	53.81	31.2	1.0	1.31	5.33	0.86	4.30	0.83
	69.7	-	-	-	-	-	-	-

Sample 1, which already represented a finished product, yielded the following results, given in Table 57, upon screening into three fractions: over 5 millimeters; 5 millimeters to 65 mesh; under 65 mesh.

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TABLE 57

FLUORITE CONTENT OF THE SCREENING FRACTIONS OF SAMPLE 1

<u>Coarsness of Fraction</u>	<u>Yield in Percent</u>	<u>CaF Content in Percent</u>	<u>CaF Recovery in Percent</u>
Over 5 millimeters	95.0	97.22	95.2
under 5 millimeters to 65 mesh	4.5	95.70	4.45
65 mesh	0.5	63.75	0.35
Original Material	100.0	96.9	100.0

In the exploitation of the deposit it thus proves possible to separate a small amount of high-grade concentrate by hand picking.

The amenability of Aurakhmat fluorspar to concentration on tables was tested on the ore of sample 3. The ore was crushed to 30 mesh and classified on a Richards 7-cell hindered-settling classifier. The first four fractions were concentrated on a Wilfley sand table. The last three were treated on the same table with a slime launder.

None of the fractions gave a finished concentrate, i.e. with 95 percent of CaF_2 , from the tabling. The best concentrates had only 81 percent to 90 percent. With reduction in the fluorite content of the ore fraction a sharp fall in the grade of the concentrate was in general observed. In most of the cases where a concentrate with not less than 80 percent of CaF_2 resulted, the fluorite content of the tailings was high (32-46 percent). Reprocessing of the

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concentrates increases their fluorite content but also increases the tailings losses.

Decrepiation was tested on the separate samples and gave fairly high indices (32). The first of these tests were made by the Ural Institute for Scientific Research in Chemistry "UNIKhIM" (Yatlov and Lashin).

The Aurakhmat fluorspar samples consisted (37) of separate lumps: class III, of diameter ranging from 40-50 millimeters down to a few millimeters, with 72.39 percent CaF_2 ; and class V, in the form of 100-150 millimeter lumps weighing 400-500 grams with 33.78 percent CaF_2 .

After calcination and cooling, the weighed portions were separated into the following four fractions: under 0.5 millimeters; 0.5-1.5 millimeters; 1.5-3.0 millimeters; over 3 millimeters.

The first experiments established the fact^{that}/at temperatures under 300 degrees Centigrade decrepiation took longer and did not result in adequate disintegration of the material. Disintegration reached substantial levels at 400 degrees, while further increases in temperature shortened the duration of the process and slightly improved the quality of the finer fractions.

Table 58 gives the results of the best of these experiments. The original material was a weighed 500 gram batch of lump fluorspar ranging in size from 40-50 millimeters down to a few millimeters. The conditions of the experiment are noted in the table.

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Decrepitation of the impoverished ore does not give satisfactory results.

A check of these results conducted on ore from sample 3 of the Aurakhmat deposit confirmed the accuracy of the conclusion that concentration by decrepitation results in low recovery of fluorite (12). The weight of the samples tested ranged from 3 to 5 kilograms. After the ore finer than 50 millimeters had been screened into a number of size classes, each of them was separately decrepitated and then sifted again into classes. The results of such a decrepitation test on Aurakhmat spar have already been given in Table 13, supra. On decrepitation, all of the fractions yielded a finished concentrate with 95-96 percent fluorite, but a very large amount of fluorite still remained in the tailings. Separation of the classes finer than 20 mesh was very unsatisfactory, and in consequence the total recovery in the concentrate was unsatisfactory and considerably smaller than that obtained by flotation.

TABLE 58

Conditions of Experiment	Classes in Millimeters	Yield in Percent	Content in Percent		Recovery in Percent	
			CaF ₂	SiO ₂	CaF ₂	SiO ₂
Heating to 520 degrees Centigrade	-0.5	43.6	98.48	0.35	67.70	1.16
Commencement of decrepitation at 220 degrees centigrade	+0.5 - 1.5	11.7	93.70	0.56	17.26	0.50
	+1.5 - 3.0	4.4	84.06	2.85	5.80	0.96
Duration 5 minutes	+3.0	39.4	14.90	32.28	9.24	97.38
	losses	0.9				
Original Material			100.0	68.1	100.0	100.0

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The flotation of Aurakhmat fluorspar was tested on ore samples 2 and 3.

The optimum grind for flotation of sample 2 contains 70 percent of particles passing a 100 mesh screen. The optimum grind for sample 3 was found to be about 52 percent of particles passing a 200 mesh screen. Regrinding the ore appears to do no particular damage in flotation of Aurakhmat spar.

Flotation with oleic acid was carried out in an alkaline medium. High alkalinity with oleic acid flotation encourages the selective separation of fluorite from quartz. A series of experiments with varying charges of caustic soda was run to determine the optimum pulp pH for flotation of sample 2, and repeated for sample 3.

A pH of about 10-11 gives the highest selectivity and recovery for Aurakhmat spar flotation. The optimum was found to be between 9.5 and 10 for sample 2, and to be 11.4 for sample 3.

The consumption of sodium silicate to depress quartz was studied on samples 2 and 3.

Its optimum level was around 300-400 grams per ton.

The absence of argillaceous admixtures made it possible to consider increasing the pulp density, and a series of experiments was run to check this.

Sample 2 contained the poorer ore, and two cleaner flotations were therefore employed. Only one such flotation was

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used with sample 3. Table 59 shows the results from both samples. Type I concentrates with 96.25 percent and 95.2 percent CaF_2 were obtained from samples 2 and 3 respectively, which contained 53.06 percent and 69.7 percent of CaF_2 respectively.

TABLE 59. FLOTATION OF SAMPLES 2 AND 3 OF AURAKHMAT FLUORSPARS

Products	Yield in Percent	Content CaF_2 in Percent	Recovery CaF_2 in Percent	[continued below]
Type 1 Concentrate	43.7	96.25	78.6	
Middlings I	7.9	76.64	11.3	
Middlings II	5.9	38.8	4.3	
Tailings	42.5	7.18	5.8	
Slime	--	--	--	
Flotation Feed	100.0	53.09	100.0	

	Yield in percent	Content CaF_2 in Percent	Recovery CaF_2 in Percent
Type 1 concentrate	66.1	95.2	90.7
Middlings I	3.9	65.6	3.7
Middlings II	--	--	--
Tailings	29.4	12.6	5.3
Slime	0.6	33.6	0.3
Flotation Feed	100.0	69.7	100.0

Elimination of the middlings by inclusion in the general results, as of concentration for sample 3, as well as those results themselves, were tested by flotation of this ore in a continuous flotation routing consisting of a 10-cell Farenvold flotation machine of 8.5 liter capacity for each cell.

The results of the flotation are given in Table 60.

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TABLE 60

FLOTATION OF AURAKHMAT FLUORSPARS

Products	Yield in Percent	Content in Percent			CaF ₂ Recovery in Percent
		CaF ₂	SiO ₂	CaCO ₃	
Concentrates	68.1	96.12	0.86	0.2	94.7
Tailings	31.9	11.48	--	--	5.3
Ore	100.0	69.7	--	--	100.0

The flotation cycle (rougher flotation and reprocessing the tailings from the rougher flotation) lasts 21 minutes in all.

At the present time a concentrating mill with an annual capacity of 20,000 tons of concentrate is being constructed at the site of the deposit. The fluorite content of the mill feed on which the project was based is 50 percent. The fines (under 10 millimeters) are first separated by wet screening from the ore, the coarseness of which is 120 millimeters. The resulting lump ore, from 10 to 120 millimeters in size, is picked on a picking belt to separate a 90 percent concentrate and the waste rock. The remaining ore is crushed in two passages to pass a 10 millimeter screen, deslimed and then ground in a ball mill operating in close-circuit with a classifier to under 60 mesh. The ground ore is then subjected to flotation, with both concentrate and tailings being given a cleaner flotation as well. The middlings

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from the cleaner flotation are deslimed and returned again to the cleaner flotation, yielding a type II concentrate and waste tailings.

The projected yield of the various products of the Aurakhmat mill, according to the technical plans, are given in Table 61 (page 273).

The mill layout is complicated. The various products scheduled for production could be secured in higher grades than those envisaged by the project plans. The production of an unfinished type II concentrate is superfluous. At the present time the modifications necessary for the production of higher-grade products are being made in the mill lay-out.

TABLE 61

YIELD OF PRODUCTS BY THE AURAKHMAT CONCENTRATING MILL

Serial Number	Designation	Yield in Percent	CaF ₂ Content in Percent	CaF ₂ Recovery in Percent	Remarks
1	Lump concentration (from hand picking)	8.0	90.0	14.4	Total yield of concentrates 1,2,3 is 50.5 percent; Total recovery therein is 88.8 percent.
2	Flotation Concentration II	82.0	95.0	60.0	
3	Flotation Concentrate III	10.5	70.0	14.4	
4	Tailings from Hand-Picking	6.0	15.0	1.8	
5	Tailings from Flotation	38.7	9.5	7.3	
6	Slime	4.8	21.9	2.1	
MILL FEED		100.0	50.0	100.0	

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CONCENTRATION OF THE COMPLEX FLUORSPAR ORES
OF THE TAKOB AND KHAYDARKAN DEPOSITS

Characteristics of the Takob Ores Relevant to their Amenability
to Concentration.

The ores of the Takob deposit belong mineralogically to the complex fluorspar sulfides with a preponderant quantity of the vein minerals (fluorite and quartz). The principal mineralogical components of the ore-body are fluorspar, quartz, disintegrated wall formations (granite, hornblende, feldspar), calcite, kaolin, lead glance, cerusite, sphalerite, smithsonite, calamine, hydrozincite, pyrite, etc. In addition, chemical analysis reveals the presence of a small amount of silver in the ore, and a very small amount of gold. The average CaF_2 content of those portions of the ore-body included in the workable reserves is about 56.6 percent.

The principal indices of the Takob ores which are relevant to its amenability to concentration are: fineness of the disseminated inclusions, degree of oxidation of the sulfide minerals, presence of other economic minerals, of which the flotability has not been studied.

Among the various inclusions, quartz is characterized by the most intimate concretion with fluorspar.

The high degree of oxidation of the sulfide minerals is characterized by the existence of margins corresponding to cerusite and smithson - around the lead glance and zinc blende. Analysis of

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sample 3 from the central portion of the third horizon vein showed PbS at 1.18 percent, while PbO was 1.73 percent. If the distribution of PbO as cerusite in the marginal areas is also taken into consideration, the high degree of oxidation of the sulfides is distinctly confirmed by these data. This circumstance complicates the process of removing the sulfide minerals by flotation.

The absence of barite and the low calcite content of the ore are favorable factors for flotation.

Hydrozincite and calamine are two components of this ore for which no methods of flotation are known. These minerals are primarily ores of zinc. There are, therefore, formidable obstacles to the recovery of zinc from these ores without first staging a special investigation into the flotation of these minerals.

The amenability of the Takob ores to concentration was studied on a number of samples which arrived from time to time as the exploration work progressed.

Samples 1, 2, and 3 were of high grade.

Samples 4, 5, and 6 were average samples from the second and first horizons. They represent all portions of the ore-body uncovered by shafts and considered workable reserves, i.e. with CaF_2 content of over 25 percent. The chemical analysis of the samples is given in Table 62. Samples 4 and 6 were taken from the second horizon, while sample 5 comes from the third.

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TABLE 62

<u>Name of the component</u>	<u>Sample 4</u>	<u>Sample 5</u>	<u>Sample 6</u>
CaF ₂	56.64	64.3	59.6
SiO ₂	28.80	--	--
TiO ₂	0.08	--	--
Al ₂ O ₃	3.64	--	--
Pb	3.00	1.77	3.3
Zn	1.72	1.2	--
S	0.41	--	--
CaO	0.50	--	--
MgO	0.18	--	--
CO ₂	0.39	--	--

The possibility of securing finished lead and fluorspar concentrates was studied on the high-grade samples 1 and 2. The affirmative answer to this question made it possible, during the investigation into the amenability of ore sample 3 to concentration, to inquire into the applicability of the various methods of concentration and to compare their results; and then, on the basis of these indices, to select the most efficient methods of concentration, yielding finished concentrates with high recovery of the economic minerals from the ores. A concentration routing was worked out on the quantitative, run-of-the-mine samples

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4, 5 and 6 and furnished all the qualitative and quantitative indices on which the technical project-plan for the Takob concentration mill is based.

Evaluation of the amenability of the Takob ores to concentration was performed on the high-grade samples 1 and 2. Tabling and flotation were selected as the methods for use in separating the economic minerals during the preliminary tests.

Tabling was employed to separate the lead minerals. Before concentration, the crushed ore was first classified by two methods, screening and a hydraulic classifier, while the fines (consisting of the classes finer than 100 mesh from screening and fractions VII-X from the Farenvold classifier) were not tabled. At the same time, flotation was also tested as a method of separating the lead minerals. The amenability of the fluorspar to concentration was tested only by a flotation method consisting of one rougher and two cleaner flotations. The results of these preliminary tests to evaluate the amenability of the Takob ore to concentration are shown in Table 63.

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TABLE 63

PRELIMINARY EVALUATION OF THE AMENABILITY OF THE TAKOB ORES TO CONCENTRATION

<u>Name of Product</u>	<u>Method of Concentration</u>	<u>Content in Percent</u>	
		<u>Pb</u>	<u>CaF₂</u>
Lead concentrate	Tabling (after screening)	58.4	--
Lead concentrate	Tabling (after classification)	58.0	--
Lead concentrate	Flotation	66.7	--
Fluorospars	Flotation	--	95.97

As may be seen from these data, finished concentrates of both lead and fluorspar may be obtained from the Takob ores.

It was very important to elucidate the possibility of obtaining lump or gravel fluorspar concentrates suitable for metallurgical use. The mineralogical characteristics of the ore, such as fine dissemination, excluded the possibility of any efficient method of concentrating coarse-grained material.

An experiment in concentrating the ore of sample 3 by hand picking confirmed this view.

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The preliminary evaluation of amenability to concentration was concluded by detailed tests of sample 3, with 74.32 percent CaF_2 and 2.75 percent Pb, which enabled the most efficient concentration methods to be selected for these ores. . . Decrepitation was only incomplete with Takob ores, and its results were therefore unsatisfactory.

The results of tabling for lead minerals separation were compared with those of flotation. The flotation of fluorspar was next considered. The results of the tests gave grounds for selecting flotation as the most efficient method of concentrating both lead minerals and fluorspar.

A detailed study of the amenability of the lead minerals of the Takob ore to concentration by flotation was conducted on the ores of samples 4 and 5, representing the second and first horizons of the deposit respectively. The optimum fineness of grind was studied in a series of flotation experiments with ores of varying grind, and the optimum grind was thereby shown to be when 89.9 percent of the feed will pass a 200 mesh screen.

Caustic soda and sodium carbonate was used to secure normal alkalinity of the pulp for lead flotation. The consumption of sodium carbonate required to attain the same results was shown by one series of experiments to be 10 times that of caustic soda, and with that the lead content and lead recovery were both somewhat lower. For this reason caustic soda was chosen to make the medium alkaline. To find the optimum alkalinity of the pulp a series of flotation experiments was run with varying pulp pH. A considerable

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rise in the alkalinity of the pulp increases the lead content of the concentrate but reduces the yield of the concentrate as well as the recovery of lead minerals in it. A pulp pH of 8.5 or 8.6 must be considered optimum, for this gives the highest recovery and an entirely satisfactory lead content in the rougher concentrate.

The consumption of caustic soda required to create this degree of pulp alkalinity fluctuates very violently with any changes in the hardness of the water. This consumption fluctuated, on the average, between 100 and 200 grams of caustic soda per ton of ore.

The sulfidization of the faces of the oxidized lead minerals that constitute the principal mass of all plumbiferous minerals in the ore is a very important factor in the flotation of the lead minerals in these ores. Sodium sulfite was chosen as a sulfidizer, and was charged into the ball mill at the time of grinding, to assure its prolonged contact with, and action upon, the newly formed faces of the mineral particles. A series of experiments was run to determine its optimum consumption, which was found to be 3,000 grams per ton of ore. This level assured maximum recovery of lead minerals and maximum lead content in the concentrate. Further increase in the dosage of the sulfidizer diminishes the recovery of lead.

In selecting the optimum consumption of sodium silicate, varying amounts of it were charged into the flotation tank. The results showed the optimum consumption to be 300 grams per ton of

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ore, which gave maximum recovery and maximum content of lead in the concentrate.

Potassium ethyl xanthate was used as the collector in the flotation of the lead minerals, and pine oil as the frothing agent. A series of experiments was run with varying charges of the collector to determine the amount required, and showed that increased consumption of this collector led to an increased amount of concentrate being obtained, but that an increase in lead recovery was observed only up to a level of 70 to 100 grams per ton. Any further increase in the consumption of xanthate is ineffectual, since it only makes a good deal of gangue enter the concentrate, which accounts for the increase in its yield accompanied by the decline in recovery. This also leads to a considerable fall in the lead content of the concentrate with any further increase in the xanthate dosage.

The rougher flotation of the lead minerals gives a concentrate with 28-36 percent lead. To obtain a product with a higher lead content, this concentrate is subjected to a cleaner flotation. The results of three cleaner flotation experiments are given in Table 64.

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TABLE 64

CLEANER FLOTATION OF LEAD MINERALS

Products	Yield in Percent of Flotation Feed	Yield in Percent of Experiment Feed	Pb Content in Percent	Pb Recovery in Percent
Concentrate	3.3	48.1	70.2	79.7
Middlings	3.6	51.9	4.9	6.8
Tailings	93.1	--	0.54	13.4
Concentrate	4.1	52.5	60.0	84.7
Middlings	3.7	47.5	4.2	5.2
Tailings	92.2	--	0.41	9.9
Concentrate	3.3	43.5	69.8	79.4
Middlings	4.3	56.5	6.9	10.0
Tailings	92.4	--	0.42	10.4
Original Flotation Feed	100.0	--	2.9	100.0

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The results of the experiments presented in Table 64 allow the conclusion to be drawn that a concentrate rich in lead can be obtained with a cleaner flotation. The recovery of lead, without processing the middlings, amounts to 80-84 percent. As a result of the experimental study of the flotation of the lead minerals in sample 4, from the second horizon, the following optimum conditions were determined:

1. The ore is ground so that 90 percent will pass a 200 mesh screen.
2. Sodium sulfite at the rate of 3000 grams per ton must be charged as a sulfidizer at the time of grinding.
3. Flotation is conducted at a pulp pH of 8.5 to 8.6, which requires use of 100 to 200 grams of caustic soda per ton. For the rougher flotation, which lasts 7-8 minutes, sodium silicate at 300 grams per ton and potassium ethylxanthate at 100 grams per ton, are charged into the flotation tank.
4. The cleaner flotation is conducted without further addition of agents.
5. The final product of the flotation of lead minerals is a concentrate with 55-60 percent lead content and recovery of about 80 percent of the total lead. If the middlings are processed, the recovery of lead minerals is brought up to 85 percent without impairing the quality of the concentrate.

A check of these optimum conditions, which were worked out on second-horizon ore, was made by flotation of upper-horizon ore, and

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it showed that two flotations (a rougher and a cleaner) under favorable conditions yield a concentrate with 55 percent of lead. The increased cerusite content of this sample and the reduced lead content (the sample assayed 1.77 percent lead) made it necessary to increase the consumption of the sulfidizer from 3000 to 4000 grams per ton of ore. The results of this experiment are shown in Table 65.

TABLE 65

<u>Products</u>	<u>Yield in Percent of Flotation Feed</u>	<u>Pb Content in Percent</u>	<u>Pb Recovery in Percent</u>
Lead Concentrate	2.1	55.6	68.3
Middlings	7.5	3.6	15.3
Tailings	90.4	0.3	16.4
Flotation Feed	100.0	1.77	100.0

The lead content in the tailings is 0.3 percent, which may be considered acceptable in view of the considerable oxidation of the lead minerals.

Flotation of Takob fluorspar.

In the course of the investigation, the following factors

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were studied: fineness of grind, choice of a collector, H-ion concentration (pH) in the pulp, effect and consumption of the activator, effect and optimum consumption of sodium silicate, consumption of the collector, pulp density, flotation time and mineralization of the froth.

Fineness of grind of the flotation feed.

The grind of the ore for the fluorspar flotation is related to its grind before the lead flotation. A single crushing appears to be technologically most expedient, i.e. doing without a crushing before the fluorspar flotation.

The increase in the fineness of grind to a content of over 85-90 percent of particles finer than 200 mesh has an unfavorable effect on the fluorspar flotation, resulting in a reduced fluorite content of the concentrate and also a reduced fluorite recovery. The best results of fluorspar flotation are obtained with a grind containing 85 percent of the ore particles under 200 mesh. But in view of the optimum grind preceding the lead flotation and of the expediency of having only a single crushing for the fluorite flotation, the same grind has been adopted for this as for the lead flotation, namely 89 percent finer than 200 mesh.

In connection with the choice of a collector, a detailed study of the conditions and results of flotations with Agent IMS-211 and oleic acid was made.

The influence of pulp pH on the course of fluorspar flotation was first of all subjected to detailed study. It was

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ascertained that the IMS agent gives best results in fluorspar flotations in weakly alkaline or neutral media.

The flotation of fluorspar was conducted after the lead concentrate had been taken off, i.e. in a pulp with a pH of 8.5 to 8.6. To reduce this pulp pH, varying amounts of HCl were charged. Based on a series of experiments, a pulp pH of 8.4 to 8.3 must be recognized as optimum for flotation of Takob fluorspars, and this requires charging the pulp, after the lead flotation, with HCl in an amount of about 200 grams per ton.

The pulp consistency in flotation was studied under the conditions of continuous operation. For this purpose, a laboratory flotation machine was adapted for the continuous discharge of the tailings through a rubber tube placed in the stopper of the discharge outlet. The machine was also fed continuously with pulp of constant consistency from a contact-receptacle with a mechanical agitator. Narrow limits were chosen for the pulp consistencies to be studied -- from 1:3.7 to 1:5.2 -- in view of the circumstance that in very consistent pulps the flotation of the lead minerals does badly, and that the use of very thin pulps would require a considerable increase in the volume of the flotation machine.

Within these limits of pulp consistency, the results of flotation are fairly stable and only vary slightly with fluctuating consistency. The best results are obtained with a pulp consistency of 1:4.

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Figure 26 shows the effect of temperature on the flotation of Takob ore with Agent IMS-211. At temperatures below 10 to 12 degrees, flotation is inefficient. The grade of the concentrate is less strikingly affected than the recovery.

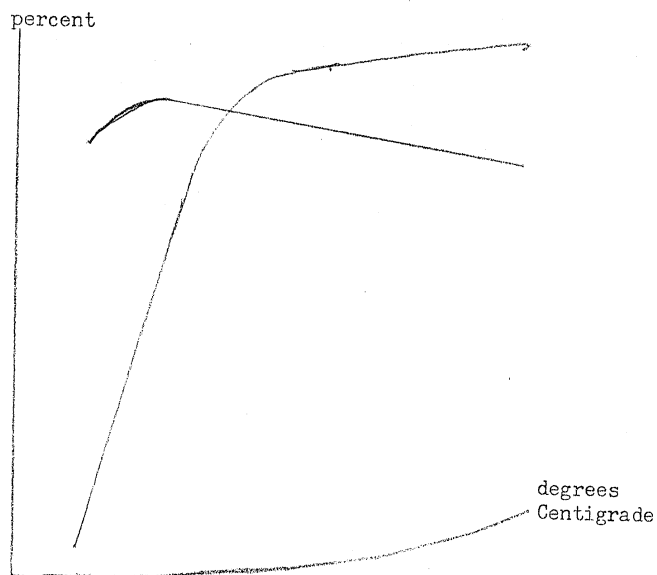


Figure 26
EFFECT OF VARYING TEMPERATURE OF THE FLOTATION OF FLUORITE WITH
AGENT IMS-211

The consumption of Agent IMS-211 was determined experimentally during flotation by fractional addition of the agent and taking off the separate fractions after each such addition of agent. The yield of the separate fractions of froth product and their respective content of fluorite is shown in Table 66.

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TABLE 66

YIELD OF FROTH-PRODUCTS WITH VARYING CONSUMPTION OF AGENT IMS-211

Consumption of Agent IMS-211 by fractions in grams per ton.	Cumulative consumption of agent IMS-211, in grams per ton.	Products	Yield in Percent	CaF ₂ Content in Percent	CaF ₂ Recovery in Percent
660	660	Concentrate I	42.8	89.3	64.2
400	1,060	Concentrate II	17.7	76.5	22.7
660	1,720	Middlings I	8.9	23.9	3.6
660	2,380	Middlings II	8.0	14.5	2.0
--	--	Tailings	22.6	19.7	7.5
		Flotation Feed	100.0	59.4	100.0

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A sharp inflection in the curve is observed after the charge of the agent has reached the level of 1060 grams per ton, both in the fluorite content of the froth product and in the fluorite recovery in the separate fractions. On further addition of the agent, the quality of the froth product falls sharply, while the fluorite content of the middlings drops even below that of the tailings remaining in the machine. The curve of dependence of the fluorite recovery in the froth product on its fluorite content (which is shown in Figure 27) has a very characteristic point of inflection. By adopting the amount of consumption of the agent that corresponds to the coordinates of the point of inflection, namely 1000 grams per ton, the most efficient separation during the rougher flotation of the original ore suspension into two products can be obtained. .

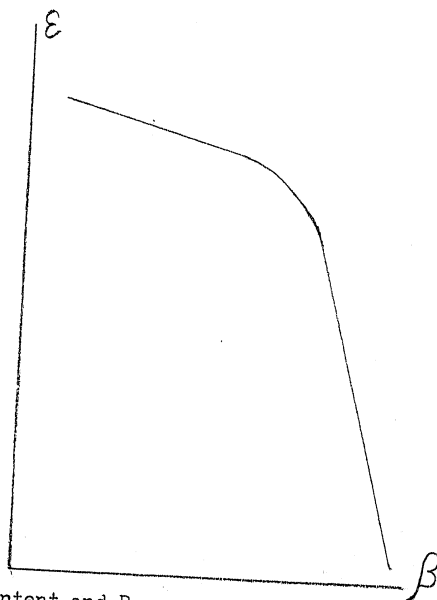


Figure 27. Content and Recovery of CaF_2 in the Concentrate in Flotation with Agent IMS-211.

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~~RESTRICTED~~The cleaner flotation.

A product with 78-85 percent CaF_2 is obtained from the rougher flotation of fluorspar with Agent IMS-211. It is given two cleaner flotations to obtain a finished concentrate. In the first cleaner flotation the consumption of sodium silicate, as the depressor for quartz, is adjusted, together with the pulp consistency. With reduction of the pulp consistency the fluorite content of the concentrate from the first cleaner flotation is insignificantly increased. This increase, however, is connected with a sharp reduction in the recovery. For this reason, the optimum consistency of the pulp during the cleaner flotation will be Solid:Liquid = 1:4 to 1:5.

A study of the action of sodium silicate on the first cleaner flotation of fluorspar determined that it had a favorable effect in amounts of about 40 grams per ton.

The concentrate from the first cleaner flotation now enters the second cleaner flotation. In view of the considerable influence of sodium silicate on the flotation process, both qualitatively and quantitatively, the search for the optimum conditions for the second cleaner flotation commenced by fixing the consumption of sodium silicate. When this is 100 grams per ton, the best results are obtained in the second cleaner flotation. Increasing it beyond this norm leads to reduction of recovery without improvement in concentrate grade.

A finished concentrate was not obtained after the second cleaner flotation. The cause of this was obviously connected with

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a sharp fall in the quality of the froth product that occurred towards the close of the second cleaner flotation. This could be observed even with the naked eye and was accompanied by a change in the color of the froth from white to a dirty gray. Reduction of the time for skimming off the froth to 3-4 minutes instead of 5 minutes resulted in a considerable improvement in the quality of the concentrate.

When the time for taking off the foam products of the second cleaner flotation was cut to 4 minutes, a finished concentrate with fluorite content of over 95 percent was obtained, with recovery about 70 percent.

Another possibility of obtaining a finished concentrate from the second cleaner flotation was also explored. This time, instead of reducing the flotation time, the charge of Agent IMS in the rougher fluorite flotation was reduced. A finished concentrate was not only not obtained, but the recovery of CaF_2 was considerably reduced in consequence.

The introduction of a third cleaner flotation made it possible to obtain a finished concentrate with complete regularity without requiring the selective skimming off of the middlings. The results of two such experiments are shown in Table 67.

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TABLE 67

Experiment Number	Products	Yield in Percent of Flotation Feed	Yield in Percent of Experiment Feed	CaF ₂ Content	CaF ₂ Recovery
1	Concentrate	45.0	85.0	95.5	72.6
	Middlings I	8.0	15.0	72.4	9.8
	Middlings I	5.7	--	--	--
	Middlings II	4.6	--	22.1	17.6
	Tailings	36.7	--	--	--
2	Flotation Feed	100.0	--	59.2	100.0
	Concentrate	36.7	85.0	97.1	60.3
	Middlings I	6.3	14.5	83.9	9.0
	Middlings I	8.0	--	--	--
	Middlings II	8.9	--	31.9	30.7
	Tailings	40.1	--	--	--
	Flotation Feed	100.0	--	59.2	100.0

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Thus as a result of the third cleaner flotation a fluorspar concentrate with 95-97 percent fluorite content was obtained.

The experimental investigations above set forth led to the determination of the following optimum conditions for fluorspar flotating with Agent IMS-211. The ore does not require regrinding after the lead flotation. The optimum pH is 8.3 to 8.4. To obtain a pulp of such alkalinity in the ore suspension following the lead flotation requires charging with acid in amounts of roughly: 200 grams to the ton of ore (with the water of the Moscow water-supply system). Consumption of sodium silicate 420 grams to the ton of ore. Consumption of Agent IMS-211 ranked from 1000 to 1200 grams per ton. The optimum pulp consistency for fluorspar flotation corresponds to a solids:liquid ratio of 1:4. Rougher flotation time 12 minutes, agitation time 4-6 minutes. Three cleaner flotations are necessary to obtain a finished concentrate. In cleaner flotations, the charging of sodium silicate improves the course of the flotation process and assures the finished grade of the concentrate and the optimum pulp consistency therein corresponds to a solids:liquids ratio of 1:5. The fluorspar concentrate after three cleaner flotations contains 95-97 percent of fluorite, with a recovery therein, without processing the middlings, of 65-70 percent of the fluorite content of the flotation feed.

The conditions and results of fluorspar flotation with oleic acid were studied in as much detail as for Agent IMS-211.

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The mean flotation indices for Takob fluorspar for both agents are set forth in Table 68.

The diagram in Figure 20 was constructed from these data. Beta along the axis of abscissae, represents the fluorite content of the concentrate, while , along the axis of ordinates, represents the recovery of fluorite in the concentrate, for flotations with oleic acid and Agent IMS-211.

The curves have the form of straight lines. That for Agent IMS-211 is flatter than the steeply descending line for oleic acid. With increasing fluorite content in the concentrate, the recovery falls more sharply for the steeply descending line of oleic acid. The point of intersection of the two lines corresponds to a 92 percent fluorite content in the concentrate. When a concentrate with more than 92 percent is obtained, Agent IMS-211 will give a higher recovery in it. These data apply to flotations without processing the middlings. The data on middlings treatment are even more favorable to the IMS reagent.

[See next page for table]

It must also be taken into account in this connection that the flotation results set forth above, obtained with Agent IMS-211 which is prepared from technical products of ordinary operational grade, i.e. such as might be obtained by the Takob concentration mill. Oleic acid of high purity was used in the laboratory tests. The quality of technical oleic acid is far inferior and lacking in uniformity and in most cases requires increased consumption and

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TABLE 68

FLOTATION OF FLUORSPAR WITH OLEIC ACID AND WITH AGENT IMS-211

	OLEIC ACID				AGENT IMS - 211							
	Concentrate		Middlings		Tailings		Concentrate		Middlings		Tailings	
	CaF ₂ Content In Percent	CaF ₂ Recovery In Percent	CaF ₂ Content In Percent	CaF ₂ Recovery In Percent	CaF ₂ Content In Percent	CaF ₂ Recovery In Percent	CaF ₂ Content In Percent	CaF ₂ Recovery In Percent	CaF ₂ Content In Percent	CaF ₂ Recovery In Percent	CaF ₂ Content In Percent	CaF ₂ Recovery In Percent
Flotation Process												
Rougher Flotation	86.0	87.0	45.0	4	17	9	81.0	81.0	59	10	17	9
First Cleaner Flotation	92.0	68.0	54.0	19	--	--	89.9	70.0	35	11	--	--
Second Cleaner Flotation	96.0	57.0	75.0	16	--	--	96.0	62.0	61	8	--	--

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use of a solvent. From this point of view the IMS Agent tested in the laboratory comes much closer in quality to the actual collector that can be used under current operating conditions than the oleic acid does.

The mineralization of the froth was the same with both agents, which are thus of equal value in this respect, but the froth from Agent IMS had the advantage of being less persistent than that from oleic acid, and thus more convenient for use under operating conditions.

The cost of IMS Agent at present prices is 1 ruble per ton of ore to be concentrated, while that of oleic acid is 2.25 rubles.

These superiorities of Agent IMS-211 led to its adoption as collector-frothing agent for the flotation of Takob fluorspar.

The flotation of fluorspar from sample 5 (upper horizon) was conducted with Agent IMS-211 under the optimum conditions worked out with sample 4.

This check confirmed the accuracy of the conditions chosen. The concentrate was of rather high grade, with fluorite content of 96.4 percent.

In constructing a concentration routing scheme for the Takob ores, it proved most desirable to return the middlings into the main stream for reprocessing, two levels above the point of their original separation. The routing also provides for reprocessing of the tailings.

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The tailings from the rougher fluorspar flotation still contain considerable quantities of fluorite -- around 20 percent. A recleaning flotation of these tailings, with normal pulp consistency corresponding to solid:liquid ratio of 1:4.5, yields a supplementary recovery of fluorite.

The tailings losses are substantially reduced. The useful product obtained from recleaning the tailings is usually poorer than the original ore, and is therefore recleaned before being returned to the main flotation stream. Middlings I from the first cleaner flotation are handled together in this same recleaner flotation. It would result in undesirable impoverishment of the feed for the rougher fluorspar flotation if these products were returned to the main stream without recleaning.

The concentration routing set up on the basis of these considerations for the Takob lead-fluorite ores is shown in Figure 28.

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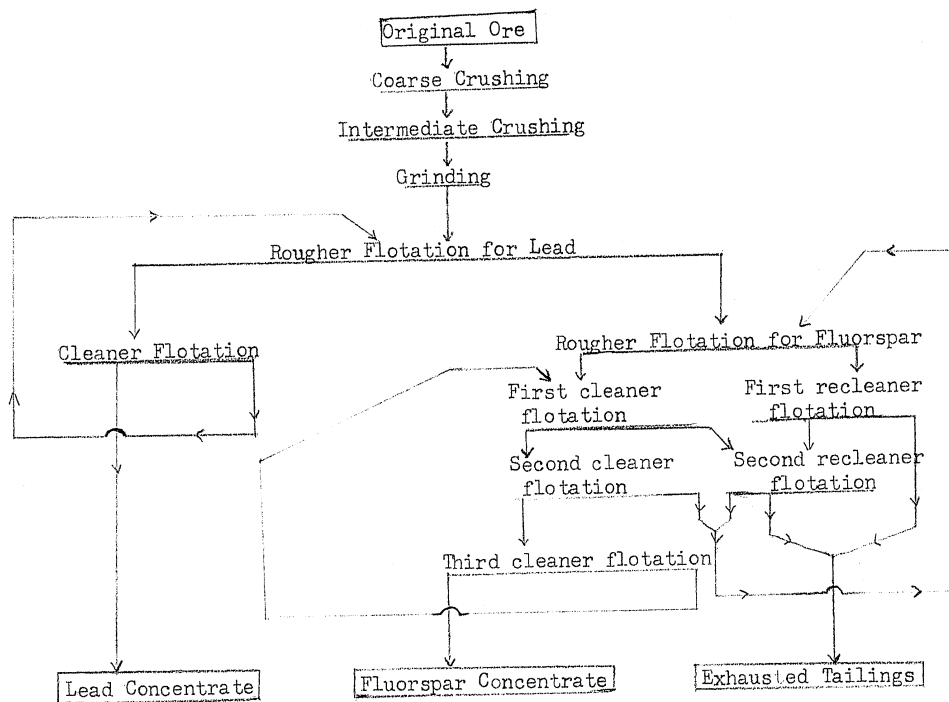


Figure 28. Flow-sheet for Concentration
of Takob Lead-Fluorite Ores

Under laboratory conditions the middlings from processing one weighed batch were added in the corresponding operation of the flotation of a second batch, so that the middlings of the previous batch were treated together with the original ore of any given batch. By the time two or three cycles had been run

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under these conditions, a fairly constant schedule had been established, under which the flotation of the original ore in a single cycle with the middlings could be studied. The amount of middlings in a cycle fluctuated only slightly, and for practical purposes the concentrate and tailings could be regarded as the only final products of the process.

This method allowed determination, under laboratory conditions, of the results of the process including the further treatment of the middlings.

A number of the most important flotation factors were studied in a given cycle under the conditions we have explained. They included collector consumption, pulp consistency, the advisability of supplementary grinding, and sodium silicate consumption.

From the third cycle on, an almost stable circulatory routing of the middlings became established, in which the amount of the middlings being returned to the rougher flotation was about 50 percent that of the original ore handled in the same rougher flotation. The flotation of original ore together with middlings proceeds at greater intensity than that of ore alone. With an open cycle for the reagents, the grade of the concentrate is about 1-1.5 percent below that of a finished concentrate. The flotation factors, which on the whole were accurately chosen, still require some additional refinement of detail. Regrinding the middlings does not give good results. Reduction of collector consumption is likewise ineffectual. Reduction of sodium silicate

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consumption, however, in view of its accumulation in the close-circuit, did result in a good finished grade of fluorspar concentrate. The results of a few flotation experiments under such conditions are given in Table 69.

TABLE 69

Experiment and cycle	C O N C E N T R A T E			[continued below]
	Yield in Percent	CaF ₂ Content in Percent	CaF ₂ Recovery in Percent	
2-IV	50.8	96.8	84.5	
2-III	54.3	94.9	87.4	
2-V	42.0	97.9	74.6	
3-V	54.1	96.6	84.6	

T A I L I N G S		
Yield in Percent	CaF ₂ Content in Percent	CaF ₂ Recovery in Percent
49.2	18.4	15.5
45.6	16.8	12.6
58.0	24.1	25.4
45.9	20.7	15.4

A schedule of lead and fluorite distribution among the end products of the flotation, based on the most typical of these experiments, is given in Table 70 and indicates the possibility of recovering 85 percent of the lead in a concentrate with 60 percent Pb and 85.6 percent of the fluorite in a concentrate with 96 percent of CaF₂.

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If ores with fluorite content over 25 percent are included in the reserves of workable ore of the Takob deposit, the mean fluorite content of such ores is 56.6 percent, while that of lead is 2.75 percent. For this reason the average distribution presented in Table 70 was converted from an ore with 59.6 percent CaF_2 content to the basis of ore with 56.6 percent CaF_2 and 2.75 percent Pb.

[See next page for table]

Table 71 shows the yield of the separate products, their quality, and the recovery of the economic minerals in them, resulting from the concentration of ore with 56.6 percent of CaF_2 , on the basis of the calculations given in Table 71.

TABLE 71

YIELD OF END-PRODUCTS FROM THE CONCENTRATION OF TAKOB ORES

Products	Yield in Percent	LEAD		FLUORITE	
		Content in Percent	Recovery in Percent	Content in Percent	Recovery in Percent
Lead concentrate	4.2	56.0	85.0	25.0	1.9
Fluorspar concentrate	50.1	0.6	10.8	96.0	85.0
Tailings	45.7	0.3	4.2	16.2	13.1
Mill Feed	100.0	2.75	100.0	56.6	100.0

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TABLE 70

DISTRIBUTION OF LEAD AND FLUORITE AMONG THE END-PRODUCTS

PRODUCTS	Distribution I				Distribution II			
	Lead		Fluorspar		Lead		Fluorspar	
	Content in Percent	Recover in Percent	Content in Percent	Recover in Percent	Content in Percent	Recover in Percent	Content in Percent	Recover in Percent
Lead Concentrate	55.0	86.6	25.0	2.2	70.2	81.0	10.5	0.7
Fluorite Concentrate	0.46	13.4	94.9	85.1	0.7	19.0	96.8	86.1
Tailings			16.8	11.7			18.4	13.2
Mill Feed	3.3	100.0	59.6	100.0	3.3	100.0	59.6	100.0

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[TABLE 70 CONTINUED]

Products	Distribution III				Average			
	Lead		Fluorspar		Lead		Fluorspar	
	Percent content in	Percent Recover in	Percent Content in	Percent Recover in	Percent Content in	Percent Recover in	Percent Content in	Percent Recover in
Lead Concentrates	57.0	85.0	22.0	2.0	60.6	85.0	19.2	1.6
Fluorite Concentrate	0.4	6.0	96.6	84.0	} 0	} 15.0	96.0	85.6
Tailings	0.7	9.0	20.3	14.0			18.5	13.2
Mill Feed	3.3	100.0	59.6	100.0	3.3	100.0	59.6	100.0

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We now consider the question of the recovery of the remaining constituents of the ore.

Zinc

Preliminary tests on sample 3 revealed that the recovery of zinc by flotation from this ore is most unsatisfactory. Zinc occurs here in the form of minerals whose amenability to flotation has not yet been studied, namely of hydrozincite and calamine. During the investigation of the amenability of ore sample 4 to concentration, the beneficiation of zinc in the various flotation products was incidentally considered. Like the investigation of the action of sulfidizers, the study of the influence of H-ion concentration on the flotation of the zinc minerals in the Takob ore yielded no results whatsoever. These preliminary experiments thus failed to result in the beneficiation of zinc from any of the flotation products.

Gold and Silver

The silver content of the crude ore is very slight. Gold is present in fluctuating but very small amounts. Silver is associated with the lead minerals, whose extraction during the flotation routing is most satisfactory. To elucidate the distribution of the precious metals in the end-products of flotation, these products from sample 6 were assayed for gold and silver after treatment in close circuit with the middlings. It appeared that almost all the silver was concentrated in the lead product. Concentration of gold was not found in any product. Assay of the end products of flotation for the precious metals showed a considerable silver content.

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In view of the fact that the recovery of the lead minerals associated with silver amounts to 85 percent, the recovery of silver to roughly the same extent must be considered assured.

Low-grade Ores.

The amenability of the low-grade ores to concentration is of considerable interest for the evaluation of the Takob deposit, and was studied on samples 7, 8 and 9.

Concentration of sample 7, which consisted of low-grade fluorite granites with average fluorite content of 17 percent, conducted according to the routing adopted for the concentration of Takob ores, yielded 10.2 percent of a concentrate with 95 percent CaF_2 .

These data show that a finished fluorspar concentrate can be obtained by flotation of low-grade fluorite granites.

A finished concentrate was likewise obtained by flotation of sample 9, which consisted of ore from surface workings of the Takob deposit with 29.2 percent average fluorite content. Table 72 gives the data of one of these experiments.

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TABLE 72

FLOTATION OF LOW-GRADE ORES IN SAMPLE 9

<u>Products</u>	<u>Yield in Percent</u>	<u>CaF₂ Content in Percent</u>	<u>CaF₂ Recovery in Percent</u>
Lead Concen- trate	1.6	--	--
Fluorspar Concentrate	18.6	95.5	60.8
Middlings	11.2	--	15.9 ¹
Tailings	68.6	9.9	23.3
Flotation Feed	--	29.2	100.0

Thus the concentration of the low-grade ores which may be obtained by including the very considerable quantity of fluorite-bearing granites in the reserves of workable ore, still affords one more opportunity for producing a fluorspar that meets the technical requirements. This fact becomes particularly apparent if the flotation results for sample 8 are considered. Sample 8 is an average sample of second horizon ores, and includes all portions of the ore-body with more than 5 percent of fluorite. Flotation of this ore, which had a CaF₂ content of 44.4 percent, yielded a high-grade spar concentrate. Table 73 shows the results of one of the fluorite flotations conducted on a continuous

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operation MS [Minerals Separation] laboratory flotation machine with a capacity of 4 kilograms per hour. Fluorite recovery in the lead concentrate was 2.5 percent.

TABLE 73

FLUORITE FLOTATION OF LOW-GRADE TAKOB ORES

<u>Products</u>	<u>Yield in Percent</u>	<u>CaF₂ Content in Percent</u>	<u>CaF₂ Recover in Percent</u>	
			<u>of experiment</u>	<u>of mill feed</u>
Fluorite Concentrate	42.2	97.3	92.5	90.2
Tailings I	48.5	2.3	2.5	2.4
Tailings II	9.3	24.0	5.0	4.9
Mill Feed	100.0	44.3	100.0	97.5

These data show that even if the low-grade fluorite-bearing granites are included in the workable reserves of the Takob deposit, the concentration of the Takob ores according to the adopted routing still remains entirely feasible technically.

The construction of a concentration mill with an annual capacity of 30,000 tons of concentrate has been commenced at the

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site of the Takob deposit, based on the above described re-searches of the IMS.

The ores of the Khaidarkan deposit are distinguished by their great variety in mineralogical composition and in their content of the individual components. Fluorspar is encountered in more or less significant amounts, but not in all ores and nowhere in quantities large enough to form ores that it would be economic to work for fluorite alone. The fluorite here can be treated as one constituent of a complex ore, the principal value of which is represented by mercury and antimony.

The amenability of the Khaidarkan ores to concentration was studied on four samples [33], which sharply differed from each other. Two of them contained fluorite in only negligible amounts (0.23-1.85 percent). One of these was studied in MEKhanOBR, and the other in the Institute of Applied Mineralogy. The chemical analysis of these samples is given in Table 74.

TABLE 74
CHEMICAL ANALYSIS OF TWO KHAIDARKAN ORE SAMPLES

<u>Component</u>	<u>Content in Percent</u>	
	<u>Sample 1</u>	<u>Sample 2</u>
CaF ₂	18.89	10.32
Fe	1.19	--
SiO ₂	70.28	72.29

[Continued next page]

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[TABLE 74 - CONTINUED]

<u>Component</u>	<u>Content in Percent</u>	
	<u>Sample 1</u>	<u>Sample 2</u>
Al_2O_3	2.01	6.19
CaO	1.04	1.52
MgO	0.34	0.08
S	0.48	0.04

The samples also contained certain amounts of Hg, Sb and As.

Two methods of concentration were used on the samples: tabling and flotation.

Wet concentration on tables was done on products of two sizes: under 1 millimeter and under 0.5 millimeters. A Richards hydraulic classifier was used to classify each of these into fractions. The coarse fractions were treated on a Deister-Overstrom sand table, and the fine fractions on a slime table of the same model. The slimes were not tabled. Tabling of the

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[TABLE 74 - CONTINUED]

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product finer than 0.5 millimeter gave the best results, which are shown in Table 75, in which the similar products of the treatment of various fractions are combined into combined products.

The middlings contained respectable quantities of fluorite (up to 30 percent), and 60-65 percent of quartz, and concretions of antimony glance with quartz, free antimony glance, and cinnabar in concretions with quartz. The tailings consisted of 85-90 percent quartz, and still contained fluorite in free granules and in concretions with quartz, as well as sulfides in concretions with quartz.

TABLE 75

CONCENTRATION OF SEPARATE FRACTIONS OF THE PRODUCT FROM 0.5 MILLIMETERS
DOWN TO 0 ON DEISTER-OVERSTROM TABLES

<u>Products</u>	<u>Content in Percent</u>		<u>Recovery in Percent</u>	
	<u>Mercury</u>	<u>Antimony</u>	<u>Mercury</u>	<u>Antimony</u>
Mercury Concentrate	19.77	35.47	29.81	2.00
Antimony Concentrate	0.64	29.45	13.04	22.46
Middlings	0.057	2.89	14.27	27.30
Tailings	0.080	1.94	13.05	16.47
Slimes from Hydraulic Classification	0.31	8.81	29.83	31.77

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This experiment, which is the better of the two, yielded entirely unsatisfactory results, for it failed to achieve any distinct separation of the component minerals.

The next experiments were made to test the amenability of the ore to concentration by flotation.

A number of series of experiments were run under varying conditions to elucidate the possibility of obtaining a combined mercury-antimony concentrate with subsequent separation of the fluorite from the tailings. Xanthate and pine oil were used as agents.

Better recovery of the metallic minerals in the concentrate was noted after prolonged crushing of the feed (90 minutes), which crushing gave a material of the following granular composition: over 100-mesh, 0.07 percent; 100 to 200-mesh, 9.63 percent; under 200 mesh, 90.30 percent.

Two cleaner flotations were given and two different sets of media were used. Both cleaner flotations were either in an alkaline medium or in one acidified with sulfuric acid.

Flotation in the acid medium yields a larger amount of concentrate, but subsequently interferes with the fluorite flotation, which goes well in an alkaline medium.

In flotation of ore milled to contain 90 percent of particles finer than 200 mesh, the flotation conditions for metallic minerals worked out for sample 1 were found to give unsatisfactory results for sample 2. After new conditions had been chosen and a number

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of collectors had been tested, the flotation of the metallic minerals of sample 2 gave the results shown in Table 76.

[See next page for table]

Isoamyl xanthate gave the highest grade mercury concentrate. The recovery of antimony was most unsatisfactory in all cases, which is presumably due to the considerable oxidation of the stibnite.

The flotation of the fluorite from the tailings of the mercury flotation, containing 10.41 percent of CaF_2 , requires careful working out of the optimum conditions.

A few experiments to fix the consumption of sodium silicate showed that it should be used in large amounts, about 1500 to 2000 grams per ton.

A concentrate with 83 to 85 percent fluorite was obtained in a number of experiments run on a routing consisting of one rougher and four cleaner flotations.

Table 77 gives the results of three of these experiments. The following was the consumption of agents: oleic acid, 200-350 grams per ton; sodium silicate, 1500 grams per ton in the rougher flotation, 1000-2000 grams per ton in the first cleaner flotation, 500 grams per ton in the second cleaner flotation, and around 250 grams per ton in the third and fourth cleaner flotation.

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TABLE 76
FLOTATION OF THE METALLIC MINERALS OF THE KHAIDARKAN ORES

Collector Consumption in Grams per Ton	Products	Content in Percent		Recovery in Percent	
		Mercury	Antimony	Mercury	Antimony
Ethyl Xanthate 300	Concentrate	2.24	3.73	54.11	15.06
	Middlings	0.91	4.45	25.77	21.06
	Tailings	0.04	0.76	20.12	63.88
Butyl Xanthate 300	Concentrate	2.31	4.81	62.85	21.44
	Middlings	0.97	5.81	18.31	17.61
	Tailings	0.037	0.73	18.84	60.90
Isoamyl Xanthate 175	Concentrate	3.55	8.62	73.19	18.53
	Middlings	0.77	5.84	8.43	11.40
	Tailings	0.03	0.81	18.38	70.0

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TABLE 77
FLOTATION OF KHAIDARKAN FLUORITE WITH FOUR CLEANER FLOTATIONS

<u>Products</u>	<u>Yield in Percent</u>	<u>CaF₂ Content in Percent</u>	<u>CaF₂ Recovery in Percent</u>
Concentrate	4.4	85.0	43.4
Middlings	17.8	24.89	51.4
Tailings	77.8	0.58	5.2
Concentrate	5.9	83.08	55.9
Middlings	31.9	9.69	35.3
Tailings	62.2	1.24	8.8
Concentrate	3.6	91.84	33.8
Middlings	30.0	17.33	53.1
Tailings	66.4	1.94	13.1

The concentrates obtained contain 83.08 percent and 91.84 percent CaF₂, i.e. a concentrate of higher grade than that from sample 1 is obtained from an ore only half as rich in fluorite. Tailings losses are slight, but a considerable amount of fluorite remains in the middlings.

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A certain refinement of the flotation conditions showed the production of a higher grade fluorite concentrate to be entirely feasible. Table 78 gives the results of one of these experiments. The conditions were as follows: oleic acid, 375 grams per ton; sodium silicate, 1500 grams per ton in the rougher flotation, and 1000 grams per ton in the first cleaner flotation, and around 500 grams per ton in the second, third and fourth cleaner flotations. After taking off the concentrate from the fourth cleaner flotation, 125 grams of oleic acid per ton were supplementarily charged and concentrate II taken off.

The results of these preliminary tests demonstrated the possibility of obtaining a finished fluorite concentrate by flotation. The conditions for the cleaner flotations, however, still demand further elaboration.

TABLE 78

FLOTATION OF KHAIDARKAN FLUORITE

<u>Products</u>	<u>Yield in Percent</u>	<u>CaF₂ Content in Percent</u>	<u>CaF₂ Recovery in Percent</u>
Concentrate I	3.3	93.50	34.29
Concentrate II	2.3	80.04	20.46
	5.6	87.97	
Middlings	31.5	9.81	34.34
Tailings	62.9	1.56	10.91
Ore	100.0	9.0	100.0

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CONCENTRATION OF FLUORSPAR FROM THE AMDERMA AND BADAM DEPOSITS

The fluorspar ore of the Amerma deposit is a quartzified limestone, enriched in fluorite, and the CaF_2 content of this ore fluctuates within wide limits from 25 to 60 percent.

The ore contains a small amount of sphalerite and may be regarded as a complex ore. It is found in a number of varieties with very low carbonate content whose concentration presents no special problems. The principal variety of Amerma fluorspar contains fluorite, quartz, calcite, limestone, sphalerite, and very small amounts of pyrite and other sulfides.

A number of separate samples, not characterizing the deposit as a whole, were tested for amenability to concentration. Subsequently a study was made of an average sample taken from the banks of the second stratum and characterizing the whole of the uncovered portion of the second stratum.

A concentrate containing about 90-95 percent of fluorite can be obtained by hand picking from Amerma fluorspar.

The ore for hand picking is first screened through a 15 millimeter screen to remove the fines, which are present in fairly large amounts.

Jigging

Some data on jigging Amerma fluorspar has been given in the chapter on "Concentration Methods", supra. Tests of the amenability to concentration by jigwork were made with a Harz-type jig. The basic difficulty in jigging this ore was the

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removal of the pyrite to cut the sulfur content of the gravel-type concentrate. The routing for the jigwork has been shown in Figure 1.

This routing removed 80-90 percent of the sulfides as tailings, and the grade of the finished concentrate can then be brought up to a 90-94 percent fluorite content.

The flotation of Amderma fluorspar has been studied in the GINTsVETMET, in the MEDHANCER and in the laboratory of the Vaychag Mining Trust of GLAVSEVMORPUT'. The principal varieties of Amderma fluorspar -- quartz-fluorite and fluoritized limestone -- behave differently to flotation concentration. The flotation of the quartz-fluorite type has been studied in the GINTsVETMET and the Vaychag laboratory.

The GINTsVETMET studied flotation conditions for an ore containing 49.9 percent fluorite and only 1.3 percent CaO, and found the optimum grind to be for 77.7 percent of the particles to pass a 200-mesh screen. The consumption of agents for the zinc flotation was fixed as follows, in grams per ton: sodium silicate, 500; copper sulfate, 500; butyl xanthate, 120; pine oil, 40. For the fluorspar flotation the pulp is charged with caustic soda to reach a pH of 7.8 to 8.1. The consumption of agents for the fluorspar flotation, in grams per ton, is as follows: oleic acid, 100; pine oil, 50. Flotation is carried out by a rather elaborate routing, including a rougher and two cleaner flotations for zinc, a rougher and two cleaner flotations for fluorite, and a recleaning flotation for the tailings and middlings of the fluorspar flotation.

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The fluorite concentrate thus obtained contains only 92.4 percent CaF_2 , and is thus of unfinished grade. The recovery without processing the middlings is most unsatisfactory, amounting to only 42.1 percent of the total fluorite content of the feed. Thus the GINTsVETMET did not succeed in solving the problem of concentrating the quartz-fluorite variety of Andermin fluorspar.

The work of the Vaychag laboratory established the possibility of obtaining entirely finished concentrates from quartz-fluorite ores with 46-70 percent of fluorite.

Flotation here proceeded by a continuous process according to a routing including a rougher flotation, two cleaner flotations of the concentrate and two of the tailings.

The consumption of agents, in grams per ton, was as follows: boric acid, 75-150; oleic acid, 90-180; Petrov contact, 135-290; pine oil, 65. Fineness of grind, according to analysis by a slurry classifier, was 95.1 percent to pass a 150-mesh screen. Table 79 shows the results of these experiments.

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TABLE 79

FLOTATION OF AMDERMA QUARTZ-FLUORITE ORES

<u>Products</u>	<u>Yield in Percent</u>	<u>CaF₂ Content in Percent</u>	<u>CaF₂ Recovery in Percent</u>	<u>Products</u>	<u>Yield in Percent</u>	<u>CaF₂ Content in Percent</u>	<u>CaF₂ Recovery in Percent</u>
Concentrate	70.4	96.7	97.2	Concentrate	70.5	96.0	98.0
Tailings	29.6	6.8	2.8	Tailings	29.5	4.5	2.0
Ore	100.0	70.0	100.0	Ore	100.0	69.0	100.0

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Use of the new Agent No 2 brought the flotation indices up to those shown in Table 80.

In experiment No 1 there were three cleaner flotations of the rougher concentrate, and one recleaning flotation each for the tailings and middlings. Consumption of agents, in grams per ton, was: agent No 2, 960 in all flotations, sodium carbonate, 2000; peptone, 50.

The average sample of the second stratum contained considerably more calcium carbonate and occasioned much more difficulty in its flotation.

This sample was screened into two fractions, finer and coarser than 25 millimeters. The coarser product was sent to the hand picking tables, where it was separated into waste rock and pure fluorite. The remaining ore, together with the fines, was concentrated by flotation.

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TABLE 80

FLOTATION OF AMERMA FLUORSPAR WITH AGENT NUMBER 2

Experiment Number	Products	Yield in Percent	CaF ₂ Content in Percent	CaF ₂ Recovery in Percent	Remarks
1	Concentrate	60.4	97.9	93.6	Flotation
	Middlings	13.2	17.2	3.5	in
	Tailings	26.4	6.8	2.9	open
	Ore	100.0	63.2	100.0	Circuit
2	Concentrate	43.0	98.6	93.0	Flotation
	Tailings	57.0	5.65	7.0	in continuous
	Ore	100.0	46.0	100.0	process

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Table 81 shows the yield of products from hand picking.

TABLE 81
YIELD OF PRODUCTS FROM HAND PICKING

<u>Products</u>	<u>Yield in Percent</u>	<u>Content in Percent</u>			
		<u>CaF₂</u>	<u>SiO₂</u>	<u>CaCO₃</u>	<u>Zn</u>
Waste Rock	20.4	8.7	22.5	64.0	--
Fluorspar	1.0	95.4	3.0	1.1	--
Flotation ore	78.6	47.5	30.84	19.1	0.3
Feed	100.0	40.1	38.9	28.0	--

Flotation of the run-of-the-mine ore after picking, conducted under conditions that appeared optimum for the quartz-fluorite variety of Amdurma fluorspar, gave most unsatisfactory results. When Agent No 2 was used as a collector, the concentrate obtained after three cleaner flotations contained 88.1 percent fluorite.

The use of sodium oleate gave no better results. The grade of the concentrate was no higher.

In this experiment sodium silicate was used as a depressor for the quartz.

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Attempts to find a more energetic depressant than sodium silicate for use in flotations with sodium oleate were unsuccessful.

The new Agent No 3 gave entirely satisfactory results when tested as a collector in flotation. After the proper conditions for flotation of the ore had been worked out, a high-grade fluorspar concentrate was obtained. The routing for the flotation is shown in Figure 29.

The ore is ground so that 80 percent passes a 150-mesh screen and first undergoes the zinc flotation. Copper sulphate at 350 grams per ton and xanthate [no indication what xanthate] at 110 grams per ton, are charged into the agitating vat. Pine oil at 14 grams per ton is charged into the first cell for the rougher zinc flotation. Subsequently the pulp is charged, for the recleaning of the tailings from the zinc flotation, with a supplementary amount of xanthate at 40 grams per ton and pine oil at 12 grams per ton. The results of the zinc flotation in continuous flotation process are given in Table 82. The tailings from the zinc flotation then pass to the fluorite flotation, and the pulp is charged with sodium silicate at 1000 grams per ton, turpentine at 80 grams per ton and Agent No 3 at 350 grams per ton.

The fluorite flotation was conducted in periodic action laboratory machines.

The concentrate obtained contained 97.1 percent of fluorite and only 1.2 percent of calcium carbonate. The recovery was high.

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The construction of a concentration mill has been proposed, based on the results of investigation of the Anderma deposits.

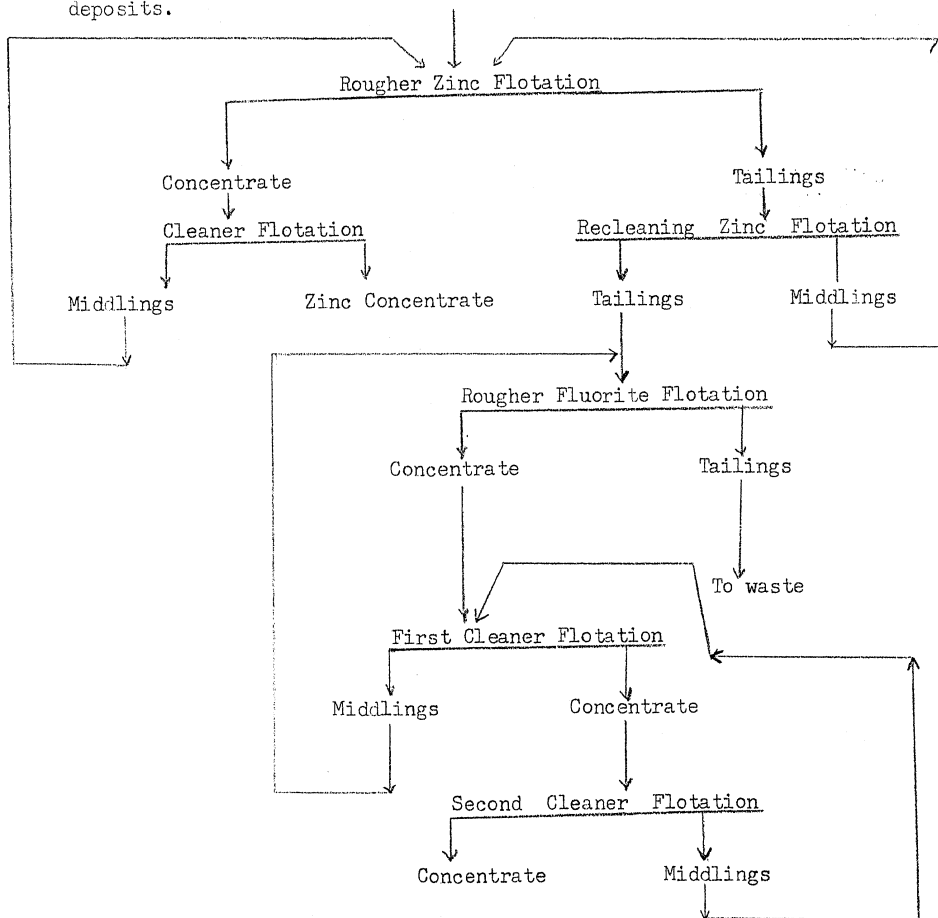


Figure 29. Flotation Routing for the Carbonate Variety of Anderma Fluorspar

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TABLE 82

FLOTATION OF AMDERMA FLUORSPAR ACCORDING TO DIAGRAM (Fig 29)

Operation	Products	Yield in Percent	Content in Percent			Recovery in Percent	
			CaF ₂	Zn	CaCO ₃	CaF ₂	Zn
Zinc							
Flotation	Zinc Concentrate	1.8	10.2	48.2	5.1	0.9	98.0
	Tailings	98.2	48.6		21.4	99.1	2.0
		100.0	48.0	0.9	21.4	100.0	100.0
Fluorite							
Flotation	Fluorite Concentrate	47.0	97.1	--	1.2	93.8	--
	Tailings	43.0	5.7	--	39.2	6.2	--

On the basis of results obtained in the Amdermink Ore Deposits, the construction of a concentrating mill is contemplated.

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The Badam deposit is distinguished by the mineralogical complexity of its ores, which are composed, in the main, of an association of four minerals: barite, fluorite, quartz and limestone. The simultaneous occurrence of all these principal minerals is characteristic for the entire deposit.

An investigation into the amenability of the Badam ores to concentration was conducted by MEKHA NOBR [10]. It used two methods for its tests: wet concentration on tables, and flotation. The object of these tests was to obtain two concentrates, one of fluorspar and one of barite, with utilization of both minerals in view.

The results of the wet process are given in Table 83.

TABLE 83
WET CONCENTRATION OF BADAM ORES

Name of Product	Yield in Percent	Content in %		Recovery in %	
		CaF ₂	BaSO ₄	CaF ₂	BaSO ₄
Concentrate	48.67	1.72	95.87	6.25	74.9
Middlings	11.68	30.35	55.28	26.45	10.4
Tailings	39.65	22.73	23.06	67.30	14.7
Feed	100.0	13.39	62.19	100.0	100.0

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A high-grade fluorite product could not be obtained by tabling.

There are formidable obstacles to the separation of fluorite from barite by flotation. These have been explained in some detail above. The attempts at flotation of the fluorite out of the Badam ores by using oleic acid and the standard depressor - sodium silicate - which were made at MEKhanOBR, gave the completely unsatisfactory results which are presented in Table 84.

[See next page for table]

At the present time, in consequence of the extensive researches of the Institute of Economic Mineralogy into the methodology of differential flotation of fluorite and barite, the essential prerequisites for the study of the conditions for the flotation-concentration of the barite-fluorite ores of the Badam deposit have been established.

THE CONCENTRATION OF FLUORITE IN THE USSR

The fluorite deposits of the USSR have been adequately studied with respect to the amenability of their ores to concentration.

Investigations have yet to be made to solve the specific problems involved in the concentration of the more complex ores, such as those of the Badam and Khaidarkan deposits. On the whole, however, the work already done in the research institutes and

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TABLE 84
FLOTATION OF BADAM ORES

Number	Name of Product	Yield in Percent	Content in Percent		Recovery in Percent	
			CaF ₂	BaSO ₄	CaF ₂	BaSO ₄
1	Concentrate	26.64	55.37	29.40	37.8	30.6
	Tailings	71.36	37.42	26.51	62.2	69.4
	Feed	100.00	41.93	27.60	100.0	100.0
2	Concentrate	27.97	15.46	17.15	29.7	31.8
	Tailings	72.03	14.22	61.70	70.3	68.2
	Feed	100.00	14.56	65.18	100.0	100.0
3	Concentrate	45.53	18.83	72.07	56.8	51.2
	Tailings	54.47	11.95	57.34	43.2	48.8
	Feed	100.0	15.08	64.06	100.0	100.0

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laboratories of the Union admits of the conclusion that, in the laboratory stage, the methodology of the concentration of fluorite ores has now been mastered.

At the same time the properties of the fluorite ores of the various separate deposits have been studied. This study has determined the possibility and the expediency of the specialization of the deposits for the maximum satisfaction of the requirements of the national economy and the most rational exploitation of the mineral resources.

The character of the ores determines the output of metallurgical grade fluorspar by the enterprises of the Transbaikalian and Amderma deposits. Efficient utilization of the ores of these deposits must lead to the production not only of lump and gravel fluorspar, but of flotation concentrates of fluorspar as well. The concentration routing recently worked out for the ores of the Solonechnoye deposit represents a rational pattern for the treatment of ores of this type.

In accordance with the properties of the several ores, this typical routing system can and should be elaborated more precisely and in greater detail.

The ores of the Khaydarkan and Takob deposits will yield only flotation concentrates. That from the Aurakhmat deposit can yield both lump and flotation concentrates.

At the present time the USSR still has not a single fluorspar concentration mill in operation. Construction of the

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Aurakhmat mill is now under way, and operation will commence in the near future. Construction of the Takob flotation mill has just commenced. When these two mills are put into production, the fluorspar industry will have the necessary technical foundation. The grade of fluorspar, especially that required for the use of the chemical industry, will be sharply improved, and the recovery of fluorite from its ores will be brought up to the normal level of the modern mineral concentration industry.

Next on the agenda stand the construction of concentration mills at Amderma and at the Transbaikal deposit, for the rational exploitation of both these deposits is impossible without such mills.

The successes achieved at the modern concentration mills of the Union (Kirovsk, formerly Khibinsk - and others) give ground for the conviction that the integration into the economy of the fluorspar concentration mills now under construction will be achieved on the basis of the research work that has been done - achieved successfully and in the shortest space of time.

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UTILIZATION OF FLUORSPAR AND THE TECHNICAL
REQUIREMENTS FOR IT

Yu. L. Chernosvitov

UTILIZATION

Industry utilizes fluorspar in two basic directions:
(a) as fluxing admixtures and (b) as a chemical raw material for obtaining a different variety of fluorine compounds. It is utilized for other purposes only in very limited quantities, for example, as a whitening agent in the glass industry, for the damping down of enamel, in the abrasive industry, in the production of calcium cyanamide, carbon electrodes, certain refractory materials, in agglomeration, in optics (transparent, colorless varieties), in jewelry work (artistically utilitarian articles and ornaments) and others.

Fluorspar was utilized for the first time in practice in the 17th century; however, up to the end of the 19th century the utilization of it remained very limited. Basic consumers of it were the glass industry, non-ferrous metallurgy, enamel production and the chemical industry, which utilized fluorspar in very insignificant quantity.

The entire world consumption of it but 35 years ago was measured at 10,000 - 15,000 tons per year.

Only in 1900, America, for the first time, used fluorspar in the smelting of basic Martin steel, and from this time the curve

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of its consumption sharply rose. Already in 1918, the world consumption of fluorspar reached its record figure of 300,000 tons, increasing, thus, thirty times in eighteen years. After the war, the demand for it lessened somewhat, but still maintained a very high level; only the crisis which set in reduced it more than ^{twice} ~~as much~~.

(a) Fluorspar, as a fluxing admixture, is used chiefly in the smelting of basic steel in the open hearth. For this purpose, not less than 70 - 75 percent of its world yield is utilized.

The addition of fluorspar, on the one hand, leads to the dilution of slags, and on the other, to the desulfurization and dephosphorization of the metal.

Limestone, the presence of which, however, in great quantities yields thick slags, on the one hand, which prevent the volatilization of the gasses, and on the other hand, which contribute to the quick and strong superheating of the metal, serves as an ordinary flux in the open hearth process. The use of slags with much lime in addition to that is exceptionally desirable, inasmuch as they strongly aid in the desulfurization and dephosphorization of the metal. The fluorspar, forming with CaSiO_3 a eutectic mixture, containing 38 percent CaF_2 , with a melting point of 1130 degrees, affords the possibility of inserting in the furnace increased portions of limestone, reducing the toughness of the slag. The addition of it contributes to the transfer of the heat of the steel, facilitates the volatilization of the gasses, accelerates the whole process of smelting and affords a general reduction of the temperature of the furnace.

Bottendorf and Wark show the twofold action of fluorspar;

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RESUME

on the one hand, thinning the slag, it makes the latter more active to itself, and on the other, it directly leads to the formation of gaseous sulfur fluoride, which is volatilized together with the product of combustion.

Zimmerman confirms the activity of desulfurization: sulfur, forming with the fluorine various compounds, is volatilized in the waste gases not entering into the composition of the slag. Fisher also indicates the formation of sulfur fluoride.

In part of the dephosphorization, according to Schwerin, the fluorspar permits the increasing of the content of lime in the slag with the preservation of its toughness and activity. This, in its turn, affords the possibility of combining a large quantity of phosphorous with the slag.

Davis expresses such a hypothesis: "it is possible that a certain quantity of CaF_2 forms fluorides with the silicon or phosphorous of the metal".

The quantity of the admixture of fluorspar depends on the raw material, the quality of the smelted metal and the conditions of smelting.

According to the data of American practice, the consumption of it fluctuates within very broad limits -- from 0.5 to 25 kilograms per 1 ton of smelted steel. The average norm for the last 6 years in the United States (in kilograms) was:

1930	1931	1932	1933	1934	1935
3.15	3.0	3.1	3.05	3.45	3.01

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In fact, seven of the chief steel foundries of the United States used in 1934 on the average per 1 ton of steel: 2.25 kilograms, 4.95 kilograms, 3.2 kilograms, 3.39 kilograms, 3.4 kilograms, 4.15 kilograms and 4.9 kilograms of fluorspar. All this permits us to consider 3 - 3.5 kilograms of fluorspar per 1 ton of metal for basic Martin steel as the normal figure of the average consumption.

Sometimes, it is possible to find an indication that the fluorspar too strongly corrodes in the furnace and lining of the ladle. Experiments of Goldman in the plant of Pol'va showed that in careful dolomitization of the furnace it is possible completely to avoid corrosion, even in the addition of fluorspar up to 1000 kilograms. Donner also confirms that.

In much less quantity, fluorspar is used in iron casting in cupola furnaces.

According to the data of French practice, pertaining to 1927, 20 kilograms of fluorspar per 1 ton of pig iron saves the enterprise 20 kilograms of coke, 20 kilograms of pig iron and 10 kilograms of limestone, affording savings of 8 francs per each ton of smelted metal. In the USSR, experiments with the use of fluorspar in cupola furnaces were conducted repeatedly. According to the data of N. P. Aksenov, at the plant "Serp and Molot" the introduction of fluorspar showed a reduction of sulfur in the pig iron from 0.14 - 0.15 to 0.10 - 0.11 percent; in the experiment at the plant "Dynamo" to 22.25 - 31.84 percent. At the same time, in considerable degree, the results of the French plants were

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confirmed; the loss of metal and the consumption of coke were reduced, the productivity of the cupola furnace was increased; the slag appeared to be so thin that it was difficult to distinguish from the smelted pig iron. However, experiments simultaneously established also negative factors -- the introduction of fluorspar led to the strong deterioration of the lining.

In very small quantities, fluorspar is used in the blast furnace and also in the Thomas process.

In non-ferrous metallurgy, it is used in the smelting of copper in shaft furnaces and reverberatory furnaces and in the smelting in flame furnaces and shaft furnaces of lead-zinc ores and tin.

A completely insignificant quantity of it is utilized in the gold-platinum and nickel industry.

The role of fluorspar in cement production is the same as in ferrous metallurgy; here also its capacity to produce a eutectic and to lower the temperature of the furnace is utilized. The addition of fluorspar to the mixture during calcination of the cement reduces the temperature of the furnace from 1400 - 1425 to 1000 - 1025 degrees. Caking without it sets in at a temperature of 1250 degrees, and with the addition of it (in an amount of 3 - 5 percent) at a temperature of 800 - 900 degrees.

To a considerable degree the fluxing action of fluorspar is used also in the employment of it in the enamel and partially also in the glass industry. However, here its capacity to make turbid

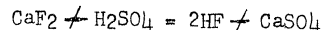
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the enamel and to impart to the glass an opalescent and even a milk-white color plays the chief role.

In enamel production it is added in an amount of 5 - 7 percent, and only in individual cases does this percentage reach 15. The quantity of fluorspar, added to the glass mixture, depends on the desired degree of whiteness of the glass. According to the American norms, for 1 ton of sand 25 to 250 kilograms of fluorspar are added.

(b) Fluorspar, as a chemical raw material, is utilized in a whole series of industries. The principal one is the production of hydrofluoric acid (HF), which is based on the disintegration of the CaF_2 by sulfuric acid (with strength in 64.5 - 65.0 degrees "Ve") with the generation of hydrogen fluoride gas, soluble then in water. The process takes place according to the following formula:



In the theoretical utilization of the raw material, the relationship of CaF_2 and H_2SO_4 amounts to $\frac{98.08}{78.07} = 1.256$; the theoretical consumption of it per unit of HF obtained is expressed for CaF_2 at 1.95, for H_2SO_4 at 2.45. Abroad, the production of hydrofluoric acid, as a rule, is carried out in apparatuses of periodical operation; however, this method, differing from the stepped-up method which is harmful to production, has an entire series of technical drawbacks, requiring a complex and huge apparatus, a large amount of working space and superfluous expenditure of manpower.

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In 1925, the Institute of Applied Mineralogy worked out a more modern method of continuous production (the authors were the Engineers M. Ye. Yakubovits and A. F. Fogt). The essence of it consists of the following. The fluorspar is ground and after drying a little is pulverized with 80 meshes in grinders of the Leshe type. The pulverized material is fed into the rotary furnace, where simultaneously is added sulfuric acid. Under the influence of the temperature, an interaction takes place between the fluorspar and the sulfuric acid, as a result of which two products are obtained hydrogen fluoride gas and gypsum. The gypsum constantly falls out in the form of a powder from a special door in the furnace, being a waste product of the production and does not participate in the further process. The gas, coming out of the furnace, passes through coke filters and further by the action of the vacuum pump is directed into the turret, where it is absorbed by water. Simultaneously, the silicide compounds of the fluorine are absorbed by the water, the former being formed as a result of the action of HF on SiO_2 , which always occurs in that or some measure, contaminating the fluorspar. As a result, an admixture of hydrofluoric acid and fluosilicic acid is obtained. In order to separate them, the mixture is poured into a tank, where a definite amount of sodium carbonate is added, leading to an intermixing at a temperature of 20 - 30 degrees. The HF which is purified in this manner is poured off, and then filtered off from NaSiF_6 . This method, checked for the first time at the Tsaritsyn Experimental Station (TsOS) of the Institute of Applied Mineralogy, was transmitted by the latter to the former Sevkhintrest and the former Alyuminstraya trust for the planning of the appropriate plant arrangements. ~~on the basis of the work done in the Urals~~ The fluoride works ^{in the Urals} at the old Polevsk plant and the new Polevsk.

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fluoride plant ^(put into operation) ~~in the fourth quarter of 1933~~ ^{are now worked on this basis.}

Technical hydrofluoric acid in the form of an aqueous solution with a content of HF of 40 - 50 percent is utilized in industry for different purposes, for example, for etching glass, the cleaning from sand of casting discharge, for obtaining hydrogen peroxide from sodium peroxide, etc.; however, basically it serves as an intermediate product for obtaining a whole series of fluorine compounds.

The production of synthetic cryolite (Na_3AlF_6) is one of the most important and responsible forms of industrial utilization of fluorspar. Cryolite is employed chiefly in the aluminum industry, where it serves as a solvent of aluminum oxide during the electrolytic deposition of metallic aluminum. In addition, it is employed on a par with fluorspar in the enamel and glass production. Abroad, natural cryolite is utilized principally, the only commercial deposit of which is located in Greenland (Ivigut). The mining of it is carried out as a monopoly by the Danish firm Aktieselskabet kryolite Mine og Haudelsselskabet in Copenhagen. The right of trade with Greenland cryolite is allowed only to two organizations: for the United States and Canada -- the American Pennsylvania Salt Manufacturing Company of Philadelphia, and for all other countries by the Danish company Oresunds chemiske Fabriker in Copenhagen.

Until the crisis, the annual production of Greenland cryolite amounted to 30,000 tons, of which 25 percent was exported to America, and the balance to other countries. It sold for eighty-five dollars and twenty-five cents a ton in 1929; by 1933 this price has fallen to seventy-two dollars.

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The production of artificial cryolite in the USSR commenced on an experimental scale in 1924, with the TsOS producing 200 - 220 tons a year. Production on an industrial scale commenced in 1929 with the opening of the fluoride shop, already mentioned above, of the Polevsk plant. In 1934 cryolite was also being produced by the new Polevsk plant, which had a scheduled output of 6500 tons, according to original project designs. [Only 1100 tons were actually produced in 1934, and 1996 tons of Greenland cryolite therefore had to be imported. This import was stopped in 1935, however, since domestic production was now adequate to supply the aluminum industry.]

The chemical composition of artificial cryolite very closely resembles that of the natural Greenland product, as is convincingly shown by the subjoined analyses, taken from the paper of Nikolayev and Koltypin in the Zhurnal Legkie Metally [Light Metals Journal] No 8 of 1934 at page 39.

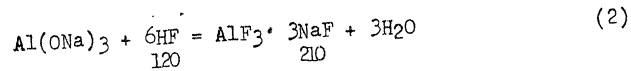
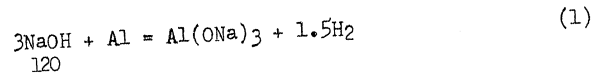
Elements	Artificial cryolite	Greenland cryolite
	in percent	in percent
Al	13.37	12.76
Na	33.07	32.99
F	54.00	53.75
Fe (metallic)	--	--
SiO ₂	--	0.03

The methods of producing artificial cryolite are fairly numerous. Its production from hydrofluoric acid is technologically simplest and economically most advantageous. Either sodium aluminate

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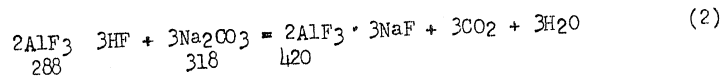
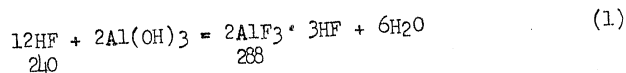
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or acid aluminum fluoride may be employed as the source of aluminum. In the former case, the reaction takes place according to the following equations:



Aluminum wastes in the form of chips, scrap, metal and oxide powders, etc., are usually employed as raw material. Technical caustic soda is used as the alkali. The hydrofluoric acid should contain 30 - 40 percent HF. The reaction must not proceed at temperatures above 50 degrees. One objection to this method is the damage to the health of the operatives which it involves; another is the rather substantial losses of HF, amounting to about 10 percent.

Another method is based on the following reactions:



The raw materials here are aluminum hydroxide and sodium carbonate. This method, carefully worked out by the Institute of Applied Mineralogy, has been adopted for the Polevsk plant. The process proceeds as follows: hydrofluoric acid is introduced into special reaction vats, where it reacts with hydrous alumina and sodium carbonate. The cryolite thus obtained is washed repeatedly and then dried. Using fluorspar with 95 percent CaF_2 content and 3.5 percent of SiO_2 , the consumption, per ton of cryolite produced, is as follows: fluorspar, 1.92 tons; 92 percent H_2SO_4 , 2.74 tons;

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Al_2O_3 , 0.275 ton; soda, 1.04 tons; water, 70 cubic meters; producer gas, 5030 cubic meters.

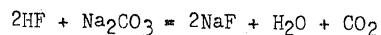
Fluorspar loss during production amounts to 25 percent, not counting the associated SiO_2 .

There are a number of other acid methods, based either on double interchange between the aluminum salts and the sodium fluoride or on the action of aluminum fluoride upon the sodium fluoride.

A method patented by Z. Kh. Korobochkin (patent No 1980) should be mentioned. It is based on the ability of fluorspar to yield compounds, in solution, of the type $\text{Al}_2\text{Fe}_4\text{SO}_4$, when treated with salts.

Sodium fluoride (NaF) may be produced by two methods: an acid method (by way of HF) or an alkaline method.

The wet acid process has been generally adopted. This is based on the reaction:



This method was developed some time ago by the Institute of Applied Mineralogy and is now employed by the TsOS and at the Polevsk plant.

A dry variant of the acid process, which has been worked out by the Institute of Applied Mineralogy, consists in passing HF gas through Na_2CO_3 . The reaction takes place in a special apparatus in the form of three parallel tubes, one above the other, through which

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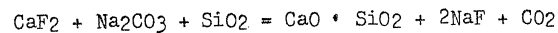
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HF at a temperature of 75 degrees and Na_2CO_3 are passed in opposite directions.

Among the alkaline processes of producing NaF, that of the Soviet engineer Sazhin must first be discussed. This method has been used at the Chita plant of the Transbaikal railroad since as early as 1924.

This method consists in fusing fluorspar, soda and quartz together in a special oven, and subsequent extraction of the sodium fluoride from the melt by leaching with water.

The reaction takes place according to the following equation:



This method has two major advantages: in the first place, it is completely free of toxic effects, since HF is not used at all; and in the second place, it allows the use of spar with a relatively low CaF_2 content (85 percent). It has, however, also a number of substantial technological disadvantages, and until these have been eliminated, its extensive application can apparently not be awaited. These are: (1) the process unavoidably yields sodium fluoride, in the first stage, in the form of a melt containing 30 percent NaF, requiring the use of immense amounts of water for leaching (25 tons of water are used in producing 1 ton of NaF); inadequate utilization of the fluorine in the fluorspar (55 - 60 percent of the theoretical amount). The evaporation requires the use of large amounts of fuel, with consequent marked adverse effect on production cost.

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The Chita plant does not employ evaporation, and ships the product to its wood-treatment plants not as sodium fluoride but directly in the form of the melt (after milling). For such uses, when the melt does not have to be transported over great distances, its production by Engineer Sazhin's method seems entirely expedient, in view of the possibility of using medium-grade fluorspar. The Institute of Applied Mineralogy has run preliminary experiments to determine the amenability of this melt to concentration. The results were most satisfactory, which gives reason to count on the possibility of further development along this line. However, the question of reducing CaF_2 losses still remains unsolved.

Sodium fluoride is mainly used to prevent decay (antiseptic) and to prevent fermentation (antifermentative). It is also used as an insecticide to some extent in place of bromine chloride and arsenic. Untreated wood lasts for 2 to 6 years in contact with earth, while when impregnated with sodium fluoride it serves for 12 - 18 years. About 420 kilograms of dry NaF are used per thousand treated ties.

Various preparations of NaF are sometimes used instead of the pure product. "Uralite", a mixture of 85 percent NaF and 15 percent dinitrophenol, is an example. Some enamel plants use NaF as an antigloss. It is also used in the ceramic and glass industries.

Sodium silicofluoride (Na_2SiF_6) can be produced by two different methods from fluorspar, either as a by-product of the acid-soda refining of fluorspar or independently by the action of sulfuric acid on highly siliceous fluorspar. The former method is of course economically more advantageous, and is used in our Polevsk

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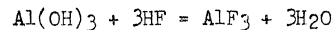
plant as a stage in the preparation of cryolite.

Not infrequently the gas SiF_4 , which is a waste product of the production of superphosphate from phosphorites or apatite concentrates, is used instead of fluorspar as a source of silicon fluoride in the preparation of sodium silicofluoride.

Na_2SiF_6 is produced in the USSR by this method at the Chernoreka, Perm and Voskresensk plants.

The principal use of sodium silicofluoride is as an agricultural pesticide, and it is used in relatively small amounts in industry: in glass-making, enamel manufacture, production of acid-proof concrete and as a preservative.

The production of aluminum fluoride (AlF_3) is usually based on the reaction



(In the Institute of Economic Mineralogy a method of obtaining AlF_3 from low-grade fluorspar has now been worked out by S. D. Kametskiy.)

Aluminum hydroxide serves as the raw material. In recent years AlF_3 has attained wide use in the aluminum industry, where it is used to regulate the cryolite baths. A bath enriched in NaF is ordinarily too viscous during electrolysis. The addition of NaF_3 reestablishes the necessary equilibrium and the contents of the bath become liquid again, thus quite respectably cutting the consumption of cryolite.

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Of the other fluorine compounds obtained from fluorspar, the following may be mentioned: aluminum oxyfluoride (AlOF), khalite ($2\text{AlF}_3 \cdot 3\text{NaF}$), ammonium fluoride (acid and neutral), barium fluoride (BaF_2), used as a preservative and in enamelling, magnesium fluoride (MgF_2), calcium fluoride (CaF_2), used for etching glass and as a preservative, calcium fluoride (KF), magnesium silicofluoride (MgSiF_6) which is added to concrete to make it firmer and more water resistant, the double salts of fluorine and antimony, and others.

We cannot fail to mention the application of a number of fluorine compounds in the construction industry. This is technically known as "fluorination".

By the deposition of "fluorators" on the surfaces of weak stone, such as, for instance, limestone, sandstone, tuff, which have slightly disintegrated under the action of atmospheric agents, a marked hardening of those surfaces (from 3 to 5 or 6 on the Moos scale) is achieved, which results in a notable increase in their resistance to climatic conditions and to pressure. Magnesium or aluminum silicofluorides are usually used as "fluorators". If it is also desired to color the stone at the same time, the silicofluorides of iron, chromium, manganese or copper are employed. Lead fluorators afford particularly good protection against the corrosive action of organic acids.

TECHNOLOGICAL REQUIREMENTS

In spite of the fact that industry has been using fluorspar for a very long time, only the USSR has industrial standards for it.

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In all other countries, not excepting the United States, its quality is set by the requirements contractually established between supplier and industrial consumer.

These requirements are fixed by various methods. Either invariable grade, or a certain minimum chemical composition may be guaranteed, sometimes with a discount for each percent of deviation, etc.

In the United States it is necessary to deal with almost ten different designations of various fluorspar grades, of which a good half are really duplications, being identical with other grades. Although the finished quality of a grade is primarily determined by chemical composition, classification according to state of aggregation comes first. The lump, gravel and ground grades are encountered in every economic survey. At the same time there are five other grades, based on use: metallurgical, enamel, glass-making, acid (chemical) and cement grades. Two new classifications occur in the customs statistics: with CaF_2 content over 97 percent, and under 97 percent.

German fluorspar is placed on the world market in six grades, consisting of various combinations of granulometric and chemical specifications: granular, from 5 to 25 millimeters, washed, 85 percent CaF_2 , maximum SiO_2 5 - 7 percent; lump size, from fist to child's head, washed, minimum CaF_2 97 percent, maximum SiO_2 1 percent; ground, minimum CaF_2 97 percent, maximum SiO_2 1 percent; lump and meal, with minimum CaF_2 98 percent; lump and meal, with guaranteed CaF_2 content 93 percent; and finally, in meal form, with minimum

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CaF₂ 96 percent to 96.5 percent. With all the variety among fluorspar grades, the technological requirements laid down abroad by the various consuming branches of industry can none the less be readily determined.

Metallurgy requires a lump or gravel fluorspar with CaF₂ content not less than 83 - 85 percent and SiO₂ from 5 to 7 percent. Any sulphur or phosphorus is considered objectionable, as these pass over into the metal. Barite not over 1 percent is tolerated. A finely ground product is unsuitable as it would be blown out of the furnace during the melt.

The chemical industry prefers the ground product but not finer than 100 mesh. The CaF₂ content demanded ranges from 95 to 98 percent. SiO₂ must not exceed 1.5 percent. Sulphur, zinc, lead and barite are objectionable. Calcium carbonate must not exceed 1.25 percent.

The glass and enamel industries prefer the lump material but also use the ground product if not finer than 30 mesh. Minimum CaF₂ is 93 - 96 percent and maximum SiO₂ 2.5 to 3 percent. Iron or calcium carbonate make a product entirely unacceptable, while the presence of lead, sulfur, barite and sphalerite is undesirable.

The cement industry uses gravel or lump spar. According to French practice, CaF₂ may be somewhat lower than in metallurgical grade.

As we have seen, the technological requirements for fluorspar are fairly stringent abroad. Fluctuation in chemical composition

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is tolerated only within narrow limits. The presence of sulfur and phosphorus is considered the most objectionable defect. Barite and silica are limited to a few percent, and it is by no means easy for many producers to stay within these limits, for both of them are usually associated with fluorspar and are difficult to separate. The chemical industry is particularly intolerant of silica, for in the course of the generally adopted acid process of producing fluorine compounds, very much CaF_2 is unproductively consumed in binding the SiO_2 . Each molecule of SiO_2 in the fluorspar binds 6 molecules of F in the form of H_2SiF_6 , and thereby reduces the yield of hydrofluoric acid. For this reason the chemical industry is interested not so much in the absolute content of CaF_2 as in its relation to the SiO_2 content. Calculation shows that if fluorspar contains 98 percent CaF_2 and 1.5 percent SiO_2 , the relation between HF and H_2SiF_6 produced will be 93.7 percent HF and 6.3 percent H_2SiF_6 , while if it contains 75 percent CaF_2 and 15 percent SiO_2 , that same relation will be 20.9 percent HF and 79.1 percent H_2SiF_6 .

The standard for fluorspar in the USSR applies only to the hand-picked product. It was worked out by the Institute of Economic Mineralogy in 1933. The draft standard was confirmed by the NKTP on October 16, 1934, at which time hand picking was still the only method used for concentrating fluorspar in the USSR.

By the average content of CaF_2 in the ore, most of our deposits of fluorspar (especially in Transbaikalia) are of unquestionably high grade. Nevertheless the mines are not in a condition to turn out the higher grades of commercial fluorspar

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by mass production since concentration is still based on hand picking. High-grade material abroad, both gravel metallurgical grade and the ground-acid grade, is produced by mechanical concentration, mainly by jigwork.

The All-Union standard OST 7633 for fluorspar, effective NKTP 655 1 March 1933, sets up three grades, I, II and III. It is stated therein that the principal users, for grade I, are the chemical producers of artificial cryolite, sodium fluoride, hydrofluoric acid, pure fluorine salts and other compounds; for grade II, the silicate and ceramic industry, as well as the production of sodium fluoride by the alkaline process; for grade III, the metallurgical industry.

Grade is determined exclusively by chemical composition. State of aggregation is not specified by the norms, inasmuch as no powder-form products (which are unsuitable for some industries, for instance, metallurgy) are produced by enterprises employing hand picking. The following technical conditions are specified:

Grade	Content	
	CaF ₂ in percent	SiO ₂ in percent
I	not less than 92	not more than 5
II	not less than 85	not specified
III	not less than 75	not more than 20

Under the heading "packing" it is provided that fluorspar shall be shipped in bulk and loaded into well-covered and cleaned cars. Shipment in barrels shall be permissible by agreement of the

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parties. Each consignment of fluorspar shipped by a supplier enterprise shall be accompanied by a certificate of origin and grade.

The standard provides detailed procedure for acceptance, regulating (a) the technique of taking a general sample, (b) the procedure for obtaining an average sample, and (c) the methods of testing.

SUBSTITUTES FOR FLUORSPAR

Ladoo considers CaCl_2 a good substitute for fluorspar in ferrous metallurgy. The experience of American plants, however, has shown this to be economically disadvantageous. The consumption of CaCl_2 is much higher than that of fluorspar, reaching 25 kilograms per ton of steel, while it is not cheaper than fluorspar. It is also very hygroscopic, and therefore requires special measures for its storage and transportation, which necessarily involve extra expense. Further according to Ladoo, ilmenite, with a TiO_2 content of 42 - 45 percent, has been tried experimentally at one of the American plants, and is said to have given better results than fluorite. There are also references in the literature to the use of sodium and potassium salts. The use of SiO_2 is likewise well known; introduced in amounts of 20 percent it affects the speed of desulphuration as fluorspar does. In larger quantities, however, it hinders desulphuration. But there can be no doubt that bauxite is the best substitute for fluorspar. As far as can be judged from isolated references in the literature, bauxite has recently won widespread acceptance for this purpose, chiefly in the German steel mills, and

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also, to some extent, in the Italian and French plants as well.

During the last three years a number of our own plants have also been experimenting with the substitution of bauxite for fluorspar, with such successful results that many of them have already completely changed over to bauxite, the use of which is beginning to grow with extraordinary rapidity. Under our conditions, where all the large fluorspar deposits are located at considerable distances from the metallurgical centers, the question of its replacement by bauxite unquestionably becomes an urgent problem of present-day significance, especially now, after the discovery in the Urals of a whole series of bauxite beds of great thickness.

A paper of F. Schonwalder in No 37 of Stahl und Eisen [Iron and Steel] for 1933, pages 949 - 952, reviewed in the journal Kachestvennaya Stal' [High-Grade Steel] No 2, 1934, pages 54 - 57, gives an account of the data of the experiments at the German plants. There is no shortage of fluorspar in Germany, and its price is relatively low. For this reason, the only object to be served by its replacement was to find a material better than fluorspar, and, specifically, one which does not corrode the lining of the furnace and of the ladle. Heats were run with French, Hungarian and German bauxite. The latter was of rather low quality with Al_2O_3 , 40 - 46 percent; Fe_2O_3 , 23 - 27 percent; SiO_2 , 4 - 8 percent; TiO_2 , 3.5 - 5.5 percent; other substances, 19 - 23 percent.

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Table 1 shows the results of the heat with Hungarian bauxite.

Table 1

Sample	Time Sample Taken		Content in Percent				Charge in Kilograms
	Hours	Minutes	C	Mn	P	S	
	1	40					90 bauxite
							dense slag
1	1	50	0.70	0.56	0.058	0.058	
							about 600 kilograms slag taken off
2	2	10	0.62	0.53	0.048	0.050	20 bauxite
3	2	20	0.57	0.50	0.042	0.045	30 bauxite
4	2	30	0.52	0.49	0.037	0.040	2 bauxite
5	2	35	0.50	0.51	0.025	0.031	
6	2	40	0.47	0.52	0.020	0.027	
7	2	45	0.46	0.51	0.020	0.025	90 FeMn + FeSi
Finished heat 3	--		0.46	0.67	0.018	0.025	--

Schonwalder notes the following respects in which bauxite is superior to fluorspar: (1) its almost instantaneous action on the slag, which becomes fluid and quickly simmers; (2) its neutral action with respect to the lining of the hearth bottom and ladle, which reduces the consumption of dolomite per ton of metal by 2 percent and increases the life of the ladles by 20 percent; (3) its neutral action with respect to the recharging of the furnace, thus permitting the amount of limestone to be increased and indirectly intensifying desulphuration; (4) its lower consumption, compared to

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that of fluorspar (instead of 100 kilograms of fluorspar, only 65 kilograms of Hungarian or 85 kilograms of German bauxite are required).

E. Killing confirms the general conclusions of Schonwalder, and likewise applies them to the data of experiments at the Julienhutte plant.

Content of S in Percent	With Bauxite		With Fluorspar	
Original content of S	0.068	0.083	0.105	0.081
Content of S in the end product	0.035	0.038	0.039	0.061

O. Scheiblich gives an unfavorable appraisal of German bauxite and points out that it has a less favorable influence on the slag than fluorspar. The factors of desulphuration and dephosphorization are not clear enough for him. He has established that bauxite encourages the rapid accretion of the hearth bottom. In view of these results, the plant at which he works considers it more expedient to run their heats on a mixture of bauxite and fluorspar than on bauxite alone.

We find a detailed description of the experimental substitution of bauxite for fluorspar in the USSR in articles by Engineer B. V. Khersonskiy and G. K. Petukhov and I. V. Kondrat'yev. Engineer Khersonskiy presents the data for seven melts with Tikhvinsk bauxite, conducted in the Martens open hearth furnace of the "Krasniy Oktyabr" plant at Stalingrad. He gives detailed analyses of all the heats and arrives at the conclusion that bauxite can completely supplant fluorspar;

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it acts upon the slag with ample speed and vigor; the slag remains basic and becomes fluid; bauxite assists the rapid solution of the aftercharged limestone and increases basicity and activity of the slag; it facilitates the draw-off of the dense slag and improves the "simmer". The consumption of bauxite, which fluctuates between 0.3 and 0.5 percent, not only does not exceed that of fluorspar, but is actually lower. Bauxite costs the "Krasniy Oktyabr" plant only a quarter as much as fluorspar.

The experiments of G. K. Petukhov and P. V. Kondrat'yev relate to the use of Alapayevsk bauxites in a basic Martens process at one of the Ural plants, and 112 melts are presented.

The results of one of these melts with bauxite are shown in Table 2 (cited from the paper of Petukhov and Kondrat'yev).

[See next page for Table 2]

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Table 2

No Samples	Time		Content in Percent			Characteristics of the Course of the Melt
	Hours	Minutes	C	Mn	P	
1	20	00	1.00	0.32	0.082	
	20	30	--	--	--	200 kg. ore added; slag drawn off
	21	00	--	--	--	200 kg. ore added; slag drawn off
2	21	10	0.55	0.11	0.035	
	21	15	--	--	--	100 kg. limestone added
3	21	45	0.32	0.11	0.023	
	21	50	--	--	--	200 kg. limestone added
	22	00	--	--	--	100 kg. limestone added
	--	--	--	--	--	50 kg. bauxite added
4	22	35	0.19	0.14	--	
	22	40	--	--	--	100 kg. ferromanganese added
5	23	10	--	--	--	50 kg. limestone added
	23	20	0.12	0.25	0.017	
	--	--	--	--	--	400 kg. ferromanganese added
6	23	25	0.12	0.41	0.012	
Final Analysis	--	--	0.19	0.33	0.011	

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The conclusions of the authors are in excellent agreement with those of Engineer Khersonskiy. Their general conclusions may be summarized as follows: (1) when bauxite is aftercharged during the course of the melt (50 - 60 kilograms with a charge of lime) during the period of slag formation, it results in more rapid formation of the slag. (2) When bauxite is introduced into the charge with a larger amount of limestone it results in instantaneous melting of the active slag. (3) The slag manifests increased activity and greater reactivity in melts with bauxite, and this factor thus favors the elimination of the phosphorus. (4) Bauxite helps to reduce the content of sulfur and non-ferrous metals. (5) The total amount of slag formed during the melt is increased, and the percentage of sulfur in the slag is also increased. (6) Bauxite intensifies the "simmer". The consumption of bauxite does not exceed 0.5 percent. Its low cost in comparison to fluorspar unquestionably makes its substitution for the latter economically advantageous. All these things taken together lead the authors to the conclusion that a changeover from fluorspar to bauxite would be expedient in the production of basic Martens steel, using fluorspar only in the most exceptional cases, for instance in the "collapse" of the hearth bottom at the end of a melt.

The data given by the authors on the desulphuration of the heat for a series of melts with bauxite is shown in Table 3.

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Table 3

Content of S in the metal, in percent

Sample No	Heat No 382	Heat No 406	Heat No 452	Heat No 9039
1	0.018	0.028	0.026	0.027
2	0.019	0.020	0.029	0.025
3	0.019	0.022	0.018	0.026
4	0.014	0.018	0.020	0.024
5	0.014	0.017	0.013	0.020
6	--	0.016	--	0.016

The substitutes for fluorspar in other branches of industry are as follows: soda and potash, in enamelling; lepidolite and bone meal, in glass making; and the waste SiF_4 gas from superphosphate plants, in the chemical industry.

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THE FLUORSPAR INDUSTRY IN THE USSR

Yu. L. Chernosvitov

HISTORICAL SKETCH AND PRESENT CONDITION

The fluorspar industry of the USSR has existed for a total of ten years.

Although a number of fluorspar deposits were known as early as the middle of the 19th century (Kalangui, Boguchan), the use of imported British fluorspar was preferred before the revolution.

Only the war, which interrupted imports -- amounting to 4600 tons in 1913 -- compelled the Czarist government to turn its attention to its own fluorspar.

In 1915 the GEOLKOM, at the insistence of the War Industries Committee, surveyed the deposits of the Ural and Transbaikalia. At that time about 70 tons were extracted from the Boguchan deposit and turned over to the Izhorsk Plant. In 1916 some small explorations on the Abagaitui deposit were made by the owner, Ziks, who extracted 1600 tons but did not remove them from the spot. In 1915 and 1916 Ryabinin, and Weber after him, investigated the Aurakhmat deposit for the first time.

During the first years that followed the revolution there was almost no demand for fluorspar. Metallurgy and the chemical industry managed to get along without it.

The extraction of fluorspar in the USSR is noted for the

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first time only in 1922, when 40 tons were mined at the IZUMRUD mines in the Urals. The next year, 1923, about 13.6 tons were mined. This fluorspar was used by the enamel shop of the Lys'yenskiy Plant.

During 1923-1924, about 2 tons were imported. This figure includes all fluorine chemicals. In 1924-1925, 282 tons were imported. In 1925 the importation of fluorspar was permanently discontinued. During very recent years, a certain amount of cryolite was imported in connection with the reviving activity of the aluminum plants (238 tons in 1932, 664 tons in 1933, and 1996 tons in 1934). Beginning in 1935 the importation of cryolite was liquidated.

The Institute for Applied Mineralogy (now the Institute of Economic Mineralogy) brought up for the first time the issue of the need for extensive study and systematic extraction of fluorspar at home in the USSR. During 1923/24 and 1924/25 it undertook exploration of the Aurakhmat deposit, which work incidentally produced small amounts of fluorspar. Owing to lack of resources, these operations could not be continued by the Institute. The 340 tons extracted by it from this deposit were turned over to industry. In 1924 and 1925 the Transbaikalia railroad commenced exploration and small-scale exploitation at the Kalangui and Sedlovsk deposits, since it was interested in acquiring a source of fluorspar for its Chita sodium fluoride plant. In 1925/26, the Institute for Applied Mineralogy again initiated studies of fluorspar deposits, transferring its investigations to the Abagaitui deposit in Transbaikalia. After carrying out exploratory work and organizing exploitation on an experimental basis, the Institute turned the Abagaitui mine over

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to the trust "RUSSKIYE SAMOTSVETY" in operating condition during the same year.

Table 1 gives the figures for the further development of the Soviet fluorspar industry. Up to 1932, exploitation was confined to Transbaikalia, first at the Abagaitui deposit, and then at the Kalangui mine, which has continued to maintain its position of primary importance.

At the present time, the fluorspar deposits are being exploited by three organizations: (1) the SOYUZPLAVNIK Trust of the GLAVNEMET of the NKTP USSR, which controls all the deposits and mines of Transbaikalia. Its head office is at Turga, near the Kalangui mine. (2) The Aurakhmat Minerals Administration, which operates only the Aurakhmat deposit, and is under the direct supervision of the GLAVNEMET. (3) The Central Administration of the Northern Maritime Route (Moscow), which exploits the Amderma deposit. In addition, a special organization called "TAKOBSTROY" was set up in 1935 within the NKTP to handle the development and exploitation of the Takob deposit.

The SOYUZPLAVNIK Trust combines six mines: Kalangui, Abagaitui, Sedlova, Otsolui, Solonechnoye and Taminga, and its ore reserves also include a number of small deposits not being worked at present (Devyataya Pyatnitsa and others).

The Kalangui mine has been intensively developed during the last four or five years, and it now leads all the above enumerated mines in the stage of exploration, scale of mining operations, yield and stage of mechanization. Fluorspar is extracted by underground working. One main shaft and three galleries have opened the deposit.

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The sinking of the shaft has not yet been completed; in 1935 it had reached a depth of only 25 meters, and it is planned to complete the sinking of the first section, to a depth of 40 meters, and to commence the work of clearing, during the third to fourth quarter of 1936. The shaft measures 2.7 x 4.6 meters in section, and its total depth, when all four horizons are worked, is to be 207 meters. Working proceeds consecutively from upper to lower levels. To reduce the amount of hoisting necessary, the existing gallery No 3 has been joined by a small cross-cut to the main shaft, and the ore will be taken out through this gallery. The projected annual output of the shaft will be 80,000 tons of ore. In 1935, the technical equipment of the mine consisted of the following: 2 13-cubic meter compressors, a 12-horsepower locomobile and 4 pneumatic drills, of which two were working on the shaft sinking, and the other two on the mine working. A considerable portion of the fluorspar is extracted manually (by blasting, with hand drilling). The mean content of CaF_2 in the ore attains 65-75 percent. Concentration is done only by hand-picking. The ore mined is first screened to separate the fines and then routed to picking tables where the gangue is removed and the ore is picked. Since hand-picking is guided exclusively by external characteristics, its success depends largely on the skill of the workers.

See next page for Table 17

The concentrate is divided into three grades, respectively containing 92 percent, 85 percent and 75 percent CaF_2 for grades I, II and III.

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TABLE 1
EXTRACTION OF FLUORSPAR (in tons)

Mines	1922	1922- 1923	1923- 1924	1924- 1925	1925- 1926	1926- 1927	1927- 1928	1928- 1929	1929- 1930	1931	1932	1933	1934	1935	1936 (plan)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
FAR EASTERN OBLAST															
1. Boguchan.	--	--	--	--	63	--	--	--	--	--	--	--	--	--	--
Transbaikalia (Since															
1933 the mines here															
have been combined															
under the "SOYUZPLAVNIK"															
Trust.															
2. Abagaitui	--	--	--	--	2814	3053	5709	16894	7839	3200	4137	9300	12000		
3. Kalangui	--	--	--	727	288	--	--	--	8711	7882	9613	17800	25000		
4. Otsolui	--	--	--	--	--	--	--	--	--	--	--	3000	4000		
5. Sedlova	--	--	--	575	--	--	--	--	--	--	--	2000	2000		
6. Solonechnoye	--	--	--	--	--	--	--	--	--	--	100	4000	8000		
7. Taminga	--	--	--	--	--	--	--	--	--	45	2508	4000	8000		

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(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Central Asia															
8. Aurakmat	--	--	180	157	--	--	--	--	--	--	--	2894	3333	3000	8000
Northern Kray (GLAVESEVMORPUT')															
9. Anderma	--	--	--	--	--	--	--	--	--	--	--	--	3600	8759	15000
Urals															
10. IZUMRUD Mines	40	13.6	35	--	--	--	--	--	--	--	--	--	--	--	--
West Siberia															
11. Suenga Deposit (KUZNETSTROY)	--	--	--	--	--	--	--	--	--	--	--	136	20	--	--
	40	13.6	215	1159	3752	840	3053	570	16894 ²	16550	11247	19388	23976	47859	68000

¹. No exact figures; extraction measured in ten-ton units.

² In addition to this, 2300 tons were extracted in a separate quarter.

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The rock mass yields about 40 percent of commercial fluorspar.

The tailings from concentration still contain a very large amount of fluorspar (up to 60 percent). At the present time they are dumped, thus in practice wasting more than half of the fluorspar extracted. According to 1935 figures, about 40,000 tons of these waste tailings have already accumulated, and it is entirely natural for the necessity of changing over to a more productive mechanical concentration method to come to the fore.

Plans for a flotation mill with a capacity of 42,500 tons of commercial fluorspar were drawn by GIPRORUDA in 1934 on the instructions of GLAVNEMET, but were not approved because of their failure to work out certain technical questions. The very great inadequacy of the technical water supply is an exceedingly unfavorable factor, which has always complicated the problem of mechanical concentration of Kalangui fluorspar. There are only two small rivers in the vicinity, the Turga and the Kalangui, with respective flows of 2.5 and 0.25 cubic meters per second. Both of them completely freeze through to the bottom.

The GIPRORUDA plans aim at maximum production of high-grade acid grade fluorspar. The great new deposits which have been discovered at Anderma and Takob now admit of another solution of the problem of producing high-quality acid-grade fluorspar and of directing the main trend of Kalangui production towards the lump metallurgical grade. A complete review of the GIPRORUDA project is thus likely to adopt a concentration routing in which flotation

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and production of the acid grade will play a secondary role, as only the tailings from the lump grade will be subjected to flotation.

In 1936 work was started on a 340 kilowatt power station. The capacity of the compressors will thus be brought up to 40 cubic meters. Work has also been started on a 40 horsepower hoist, a drainage system (25 cubic meters), a waterworks (30 cubic meters) and a crushing mill with a classifier with a capacity of 15 cubic meters of ore per hour.

According to the plan approved by the NKTP, the Kalangui mine will turn out 25,000 tons of commercial fluorspar in 1936.

The Abagaitui mine has been exploited continuously since 1925/26, and is the oldest fluorspar enterprise in Transbaikalia. It was once the main source of supply for all our industry, but with the development of the Kalangui mine its importance has gradually been declining, though it is still the foremost producer of the best acid-grade spar. It was thought to be almost completely exhausted in 1933, but explorations made by the Institute of Economic Mineralogy showed this view to be unfounded. Although the remaining reserves of the Abagaitui deposit are not as great as those at Kalangui or Solonechnoye, they are still enough to assure the continued working of the mine for a good many years. Fluorspar is being mined at present from shafts Nos 2 and 3, shaft No 1 having been closed down. Concentration is manual, and yields about 55 percent of the crude ore as commercial spar, which is higher than at Kalangui. In view of the inconsiderable thickness of the deposit,

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the construction of a concentration mill has not been proposed. The productivity of shaft No 2, which is now being worked, is being increased to 17,000 tons; in 1936 a 170 kilowatt power station with 19.5 cubic meter compressors will be placed in operation. The 1936 program envisages the output of 12,000 tons of commercial fluorspar.

Operation of the Otsolui mine commenced only in 1935. Extraction is by galleries, and the yield of commercial spar, which is produced by hand-picking, is 55 - 60 percent of the crude ore, and is distinguished by high CaF_2 content. During 1935, all work was by hand. In 1936 a 6.5 cubic meter compressor and a 10 cubic meter drainage system is being installed, bringing the output up to 4000 tons of commercial spar.

In view of the insignificant ore reserves, a changeover to mechanical concentration is not being planned; the high-grade ore of this mine yields a valuable product even with hand-picking.

Operation of the Sedlova mine likewise commenced only in 1935. In 1936 the plan calls for an output of 2000 tons of commercial spar, and for a 50 percent yield thereof from the crude ore. All work is by hand. In view of its limited reserves, this mine can play only a subordinate part.

Roughly the same indices characterize the Taminga mine, which was started up in 1933. Its spar is very friable and disintegrates on screening, so that hand-picking must be done without screening. It is intended to send the ore from this mine to the Kalangui concentration mill when the latter has been constructed.

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The Solonechnoye deposit has been worked only since 1933, in which year 100 tons were extracted in the course of the exploratory work. No mining was done in 1934.

In conclusion we furnish some additional data on the activities of SOYUZPLAVIK. In 1935 319 workmen were employed under 23 engineers and other technical personnel in all of its mines.

The Trust has a fleet of 50 trucks to deliver its production to the nearest railroad stations. Its cost of truck transport is 1 ruble per ton-kilometer.

The Aurakhmat Mining Administration is the second fluorspar producer that is directly under the GLAVNEMET. After a short period of experimental working by the Institute of Economic Mineralogy in 1925, the mine was closed down for 8 years. Detail explorations were made in 1931, and exploitation resumed in 1933. Up to February 1936, the mine was under the SOYUZKhIMRUD, and was then transferred to the GLAVNEMET system.

The Aurakhmat mine, as a matter of fact, is still passing through its organizational stage. Its exploration has not yet been entirely completed, and the construction of a concentration mill is being rushed.

The deposit has been opened up by a number of galleries. Some mining work is being done with pneumatic drills (3000 tons in 1935). The fluorspar is concentrated by hand.

With the relatively low average CaF_2 content of the ore (about 50 percent) and its unfortunate friability, the handpicking

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alone gives unsatisfactory results both in yield and grade of commercial spar turned out.

The Aurekhmat enterprise is 45 kilometers from the nearest railroad station, and the construction of an automobile highway (chaussee) is proposed. The annual productive capacity of the enterprise will be brought up to 31,000 tons of fluorspar concentrate in the fourth quarter of 1937. The 1936 plan calls for the output of 8000 tons of commercial spar. In 1935 200 workmen were employed in the exploitation. The fluorspar is marketed to industry at 200 rubles per ton.

The GLAVSEVMORPUT' has been carrying on extraction from the Amerma deposit since 1933. In spite of the difficult conditions prevalent in the far north, the Amerma enterprise has developed with exceptional speed. Simultaneously with the continuing explorations, exploitation is being carried on in two shafts of 50 meters depth. The mine has a compressor system and pneumatic drills. In 1935, 8760 tons of commercial fluorspar were produced, while about 10,000 tons were shipped to Arkhangelsk, partly from the production of the preceding year. Concentration is still done manually from a picking belt, yielding a spar of uneven quality with 75 to 98 percent CaF_2 .

In view of the low average CaF_2 content in the run-of-the-mine ore (about 30 percent) mechanical concentration appears to be an indispensable condition for rational exploitation of the Amerma deposit. MEKHA NOBR has drawn up a project for a concentration mill with an annual capacity of 50,000 tons of high-grade concentrate.

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For the time being it is necessary to work the richer sections of the mine to obtain a finished concentrate from picking.

The 1936 plan calls for the output of 15,000 tons of commercial spar, of which 10,000 tons is to be the high-quality acid grade.

The Polevsk cryolite plant is the principal consumer of Amderma spar.

The industrial production of fluorspar in the USSR is thus centered in these three enterprises at the present time. We may still mention the insignificant and incidental extraction of fluorspar at the IZUMRUD mines in the Urals, the small-scale mining operations by the KUZNETSSTROY at the Suengin deposits in Western Siberia, and, finally, the negligible amount of Ratovkite fluorite produced by the Krasniy Profintern Trust (incidentally to its 1933 and 1934 explorations, from the Zubtsov deposit in Rzhnevskiy Rayon.

There is still no mining being done at the Takob deposit. The TAKOBSTROY is building housing and putting up accessory equipment. The automobile road from the mine to the Stalinabad-Tashkent highway has been completed. The technical working plans for the mine and concentration mill with an annual capacity of 30,000 tons of fluorspar concentrate have been drawn by the GIPRORUDA.

Among the major unexploited deposits, two stand out in particular: Khaidarkan and Badam (cf. the articles of Eigheles).

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The problem of concentration has not yet been solved, however, and this is an obstacle to their exploitation. Both deposits are complex: the former is antimony-mercury-fluorspar, the latter fluorspar-barite. Study of the amenability of these ores to concentration have not, for the time being, given good results, though there are hopeful indices from the experiments made by the Institute of Economic Mineralogy. Additional exploration will also be necessary.

Up to 1934, fluorspar was considered a material in critically short supply in the USSR. According to the SOYUZMINERALSNABSYT, only 10,750 tons of fluorspar were actually received in 1933 by the 53 consumer enterprises that had filed requisitions totalling 50,000 tons. The requisitions for 1934 were for about the same amount, with total production by all enterprises amounting to 23,435 tons. In 1935 the quantitative spread between demand and production had already disappeared. Towards the beginning of 1936 a small carry-over supply can even be noted at the mines of SOYUZPLAVIK and Aurakhmat.

The matter of the quality of the output is a different story.

Although our fluorspar deposits are characterized by a relatively high average content of CaF_2 (especially in Transbaikalia) it still is impossible to obtain by manual concentration, in mass production, material that meets the exacting requirements of the chemical industry. Though individual batches might be rich in CaF_2 its average content in the normal product marketed to the chemical plants did not meet the prescribed norms (CaF_2 fluctuated

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between 85 and 92 percent). The fluorspar was usually too badly contaminated with silica, running as high as 15 percent. This was one of the principal circumstances that interfered with the smooth production of cryolite and other fluorine compounds. In 1934 and 1935 the acuteness of the situation resulting from the production of unfinished fluorspar concentrates was somewhat alleviated by the discovery of the Amdur deposit, where by working a massive lens of almost pure fluorspar a product of altogether purity could be obtained for the chemical industry.

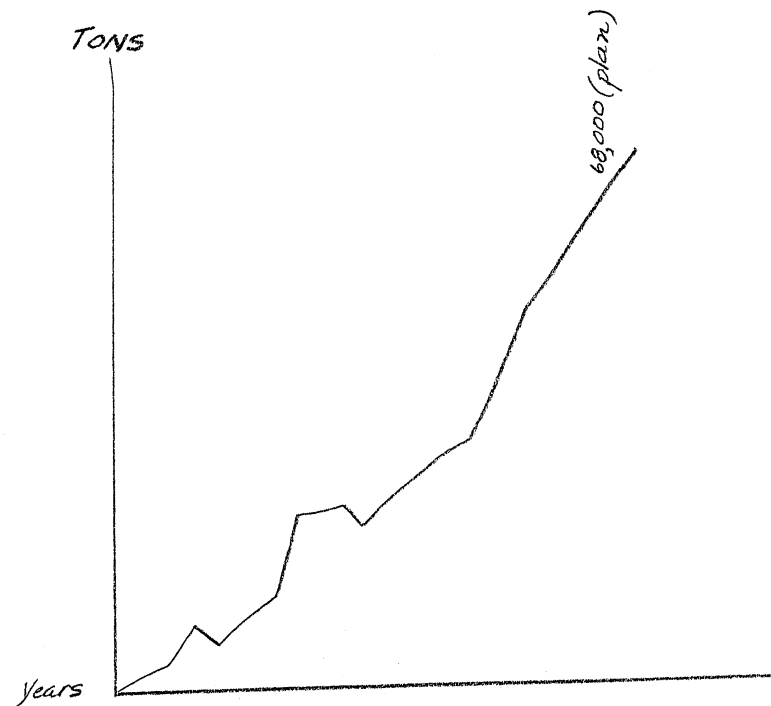


Figure 1.

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The question of the "quality" of fluorspar will be finally removed from the agenda of our fluorspar industry only after concentration mills have been put into operation.

In appraising the results achieved by the fluorspar industry of the USSR at the present time, it is impossible to lose sight of the difficult conditions under which its organization and development took place, on account of the great distances that separated all the major deposits from the consuming centers.

The absence of data on the thickness of the deposits and the quality of the ore could not fail to impede the technological investigations, and in particular the research on concentration which was essential for the formulation of projects and working plans for concentration mills.

The work of the Institute of Economic Mineralogy was a major to the study of the foundations of the fluorspar industry. Commencing with 1930, it conducted explorations on the Transbaikalian deposits for a number of years, and prepared complete industrial appraisals for those deposits. Its work on the exploration of the Takob deposit is also of great significance. It investigated the amenability of Transbaikalian and Takob ores to concentration, and then worked out a rational concentration routing for these ores and proposed it to the industry. In the field of concentration research the work of the GINTSVETMET must be mentioned, together with that of the SOYUZKhimRUD Trust, in the field of exploration, on the Aurakhmat deposit. The explorations of the Vaychag Expedition and of the GLAVSEVMORPUT' on the Amderma deposit have been of extremely great significance.

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All these investigations, taken together, have made it possible to proceed in real earnest towards the accomplishment of the tasks of reconstructing the mines and drafting the projects of concentration mills, on the one hand, and towards the intensive development of the work of exploitation, on the other.

The successes attained by the fluorspar industry during recent years are in reality truth colossal (cf. the curve of growth of production in Figure 1). We have had an increase of over 800 percent in 7 years. If we compare the dynamics of fluorspar production to the growth of steel production, we get the following picture. In 1927/28 720 tons of commercial fluorspar were produced in the USSR for every million tons of steel poured there, in 1928/29 this coefficient rose to 1940 tons, in 1930 to 2750 tons, in 1933 to 2820 tons, in 1934 it was 2480 tons, and in 1935 it reached 3760 tons. Thus in 1935 the Soviet fluorspar industry showed a higher coefficient than the United States in the years of the full flowering of its industry.

The papers printed in this collection should readily convince the reader that the future successful development of the fluorspar industry of the Union is entirely assured by its raw material base.

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RESTRICTED**THE FUNDAMENTAL LINES OF DEVELOPMENT OF THE FLUORSPAR INDUSTRY OF THE USSR WITHIN THE NEXT FEW YEARS**

In analyzing the lines of future development of the fluorspar industry of the USSR we intend to show the fundamental factors that will determine the most important changes and improvements in the position of that industry during the next few years.

Not so long ago the most complicated element of the whole fluorspar question was the quantitative and qualitative satisfaction of the needs of the artificial cryolite industry. Inasmuch as the smooth and undistorted functioning of the infant aluminum industry of the USSR depended in large measure upon the timely and adequate production of artificial cryolite, it was no more than natural that fluorspar for that purpose should receive the lion's share of attention, all the more so for the formidable obstacles which the process of hand picking involved for the preparation of such fluorspar.

To produce the 75,000 tons of metallic aluminum for which the plan provides in 1937, the amount of high-grade fluorspar (with not less than 92 percent of CaF_2) for cryolite, at the end of the Second Five-Year Plan, is calculated at about 25000 to 30000 tons, at the standard consumption rate of 200 kilograms of cryolite per ton of aluminum.

The question of the production of sodium fluoride and other fluorine compounds -- especially of aluminum fluoride -- was somewhat less urgent. In this area there was doubtless an underestimation of the importance of these chemicals, which had still not

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found very widespread use in our economy. It was thought that the alkaline process of Engineer Sazhin offered a way whereby the production of sodium fluoride could be carried on, in part, by using medium-grade fluorspar ranging in content 80 to 85 percent of CaF_2 , which could be obtained in ample quantities even by hand picking. The 1937 requirements of fluorspar for producing these fluorine compounds are calculated to be of the order of 15,000 to 20,000 tons.

For the production of 16,000,000 tons of steel in 1937, metallurgy will require, at the end of the Second Five Year Plan, not less than 45,000 to 50,000 tons of fluorspar, at the established average rate of consumption in the United States, which is about 3 kilograms per ton of metal.

Including the demand of the smaller consumers, such as glass-making, enameling, etc., the total demand for 1937, including the carry-over, was calculated at 90,000 to 100,000 tons of fluorspar, of which about 60 percent will have a CaF_2 content not higher than 85 percent. This is the approach to the problem that was taken two or three years ago.

At the present moment, however, there are at least four new factors that have very substantially changed the entire structure of fluorspar consumption and evoked corresponding advances in its production.

The first of the decree of the STO of 27 August 1935 (No. 542) on the expansion of the wood-treating industry. This decree set an expanded program of fluorspar production and of capital

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construction in the fluorspar industry during the immediately following period from 1936 to 1938.

In this decree the STO set a total treatment capacity of 6,500,000 cubic meters of wood, to be attained by 1 January 1938 by the wood-treatment plants, of which plants, 4,500,000 cubic meters capacity, was assigned to the NKPS, 450,000 to the NKTP, 1,000,000 to the NKLes, and 350,000 to the plants of the Narkomvoda. It proposes that the NKTP assure the production of 6500 tons of sodium fluoride during 1937, and that the NKPS assure not less than 3000 tons, thus bringing the total production (converted to terms of pure NSF) up to 25,000 tons by the beginning of 1938.

In accordance with this, the NKTP proposes still in 1936 to proceed with construction of two new sodium fluoride plants, one at Slavyansk with a capacity of 10,000 tons (to start operation 1 February 1937), and the other at Revd, with capacity 10,000 tons each of sodium fluoride and cryolite. The NKPS is scheduled to commence construction during 1936 of a sodium fluoride plant with a capacity of 2200 tons, to start operating on 1 January 1937. The NKPT is obligated to bring the fluorspar production up to 55,000 tons in 1937 and to 70,000 tons in 1938. The Glavsevmorput must turn out 20,000 tons in 1937 and about 50,000 tons in 1938. The first section of the Aurakhmat concentration mill, with a capacity of 15,000 tons of fluorspar, is scheduled for operation in the third quarter of 1936, and the second section, with 16,000 tons, for the fourth quarter of 1937.

We see that this decree has given the production of sodium fluoride great national-economic significance. In its importance

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it (NaF) is now on the same level with cryolite production, though in physical volume it will considerably surpass the latter. For the production of NaF alone the fluorspar industry should furnish some 30,000 tons of commercial fluorspar during 1938.

The second factor is the systematic curtailment of the cryolite consumption norms of our aluminum plants.

For the proper functioning of the cryolite bath during electrolysis, the cryolite formula must be maintained at constant level corresponding to $\text{AlF}_3 \cdot 3\text{NaF}$.

Experiments, first undertaken at the Volkhov aluminum plant and then transferred to the plant at Dnepropetrovsk, showed that by the addition of a certain quantity of AlF_3 , the bath could be "rejuvenated", i.e. that its equilibrium could be restored, thus considerably reducing the consumption of cryolite. [The addition of AlF_3 is widely practiced in France.] In the general section of the project for a fluorine-compounds plant, drawn up at one time by the Giprotsvetmet, the norm for the consumption of cryolite was taken at 210 kilograms per ton of metallic aluminum (150 kilograms for the primary charge of the bath and 60 kilograms for the re-charge.) This norm had also been the usual basis in planning the total demand for cryolite in the aluminum industry as a whole. By encouraging a rational system of electrolysis and introducing AlF_3 into the bath in the first instance, the Dnepropetrovsk (DAZ) and Volkhov (VAZ) plants now upset this norm. As early as 1933 the average cryolite consumption at the Volkhov plant had been only 118 kilograms. According to A. I. ~~Z~~heleznov, A. Gaylit, and F. Shvartsman, cryolite consumption was cut still further during

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1934, amounting to an average of 71 kilograms at the Volkhov plant and about 83 to 85 kilograms at the Dnepropetrovsk plant. 1935 brought even better results.

The data for AlF_3 consumption in kilograms per ton of aluminum during October and November, 1935, at these plants, are shown below:

	October		November	
	DAZ	VAZ	DAZ	VAZ
Cryolite	63	63	58	55
AlF_3	14	28.4	18	23

When AlF_3 is used, the economy in cryolite far exceeds the consumption of aluminum fluoride. This results in a net decline in the demand of the aluminum industry for fluorine compounds. If by adding 30 kilograms of AlF_3 , the average norm for cryolite consumption can be fixed at 60 kilograms, we have a total consumption of 90 kilograms of fluorine compounds per ton ~~as~~ against the previous norm of 210 kilograms.

It thereby becomes necessary to make the corresponding adjustments in the previous estimates of the aluminum industry's demand for cryolite, and at the same time to direct the attention of the chemical industry towards the expansion of aluminum fluoride production. About 10,000 tons of high-grade fluorspar would thus be required to fully meet the cryolite requirements of the aluminum industry under the new norm, or in other words, some two and a half to three times less than had been planned two or three years earlier. Our fluorspar producers can furnish this amount

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with no particular strain, especially after the Aurakhmat concentration mill has been placed in service. But so as not to force the aluminum plants to import AlF_3 , it became necessary to take urgent steps to expand its production in the USSR.

The third factor of immense practical importance, observed during the past one and a half or two years, has been the shift of our ferrous metallurgy to steel production with bauxite. This shift deserves special attention, since it affects the largest consumer of fluorspar as a metallurgical flux, the manufacture of basic open-hearth steel.

The insecurity of the supply of the necessary quantities of fluorspar furnished the initial impetus for the production trial heats with bauxite.

These trial heats, however, led metallurgists to the conclusion that the substitution of bauxite for fluorspar was expedient not only because the latter was in short supply, but also because of general technical and economic considerations. Thus B. Khersonskiy presented the indices that characterized the meltings with bauxite as satisfactory and calculated that the "Krasniy Oktyabr" plant would save 200,000 rubles a year by changing over from fluorspar to bauxite. The consumption of bauxite amounts to 0.3 percent to 0.5 percent, somewhat less than that of fluorspar. The cost of bauxite is 14 rubles a ton, and the freight to Stalin-grad is another 14 rubles. The total cost c.i.f. plant is 31 rubles. The saving on each ton of flux is 92 rubles. In addition, the plant does not have to keep large stock-piles of bauxite,

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as was unavoidable with the great distance of the fluorspar deposits. The size of the carry-over to 1936 of metallurgical fluorspar produced in 1935, which remained at the mines, and the reduced requisitions for it in 1936, indirectly testify to the increasing use of bauxite in 1935, compared to 1934. Figures of the COYUSALYUINSNAB^BSYT confirm this. The requisitions for bauxite by iron and steel metallurgical enterprises of 1 April 1936 had reached 74,000 tons. Excluding from this amount about 30,000 tons for the blast furnaces at the Kabakovsk and Pashinsk^S plants, we still have over 40,000 tons of bauxite for steel production, part of which, of course, goes into the charge itself, but part of it used to replace fluorspar as a flux. The steel foundries will be supplied partly with Tikhvinsk bauxite at 10 rubles a ton, f.o.b.mine, and partly with Ural bauxite from the Kikshinsk^U deposit and Krasnaya Shapochka, at 20 rubles a ton f.o.b. station of destination.

These figures show that the use of bauxite in place of fluorspar is beginning to take on formidable proportions in the USSR. It is entirely clear that if this substitution continues to gain ground, it will exert a great influence not only on the structure of fluorspar consumption, but on the volume of its production as well.

The discovery of a large number of major bauxite deposits in the Urals is a favorable basis for its introduction as a flux.

This third factor should be studied from all sides, and with the utmost care, by the research institutes and the controlling and planning bodies concerned, in view of its colossal significance both for the iron and steel metallurgical industry and for the further development of the fluorite industry of the USSR.

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However, no matter how promising the experiments at substituting bauxite for fluorspar may seem to be, it would be a serious error to think that fluorspar in general was losing its importance as a flux in ferrous metallurgy. Not to mention the rapid growth of electric furnace production of steel, the production of ferro-alloys and pig-iron castings, which use respectable quantities of fluorspar, the Martens process, too, cannot get along entirely without it, even though it switches over to bauxite as a general rule. The experience of Germany and of our own plants shows bauxite to be inapplicable in case of collapse of the hearth bottom; and the same experience also shows that some of the German plants prefer to work with a mixture of bauxite and fluorspar instead of with pure bauxite. With us there is all the more reason for proceeding with deliberation and caution in substituting bauxite for fluorspar in that our plants were prompted in the first place to take up this substitution by the short supply and relatively high cost of fluorspar. Today, as we know, the first of these reasons has been eliminated, and in the near future the second will also be eliminated.

Finally for the fourth decisive factor: the discovery of two new fluorspar deposits of exceedingly great thickness -- at Amderma and Takob.

The initial studies in the USSR of the amenability of fluorspar to concentration laid very great emphasis on the procurement of the greatest possible amount of the acid grade with exceptionally high CaF_2 content, without taking into account either the natural

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peculiarities of the ores or the requirements of ferrous metallurgy. This was due to the effort to give priority to the satisfaction of the cryolite production.

In consequence all concentration routings, including those proposed for the Transbaikalian deposits, were based on the flotation principle, which unavoidably yields a product with a high degree of dispersion. The interests of ferrous metallurgy, which require the lump product, were thus disregarded.

The discovery of the Amderma and Takob deposits, making available vast new sources of acid-grade fluorspar (from flotation), afford an exceedingly favorable opportunity of correcting this miscalculation. The decree of 27 August 1935 by the STO completely solves the problem of assuring a supply of fluorspar for the chemical industry by prescribing the magnitude, sequence and time-limits of the expansion of production at Amderma and Aurakhmat. The great Takob enterprise will go into production in the near future. The switching over of the chemical industry to the fluorspars of Amderma and Central Asia now admits of the fullest utilization of the valuable natural qualities of the fluorspars of the Transbaikalian deposits, directing their basic line of production towards the output of the lump metallurgical grade. Only the tailings from hand picking and jigwork are now to be subjected to flotation. As a result of the recent investigations by the Institute of Economic Mineralogy, it will now apparently be feasible to introduce jigwork into the routings for Kalangui and Solonechnoye.

The construction of the Kalangui concentration mill must

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be considered of primary importance, for this deposit is best prepared for large-scale mining operations. Simultaneously it is necessary also to prepare the Solonechnoye mine for operation.

Together with this, all possible measures should be taken for the procurement of a certain amount of the metallurgical grade at Amderma as well (8000 to 12,000 tons) to supply the plants of the Leningrad Oblast and the central regions. The production of the metallurgical grade by the Amderma enterprise, alongside of the acid grade, appears extremely desirable in view of the great distance of the Transbaikalian deposits.

We may conclude our survey with the following short resumé:

1. The fluorspar industry of the USSR is entirely the achievement of the Soviet authority. Fluorspar was not mined in pre-revolutionary Russia, and not a single deposit was studied.

2. A characteristic feature of the mineral sources of fluorspar in the USSR is their great distance from the consuming centers. All of the major industrial deposits of this mineral occur in the outlying regions which are still only imperfectly integrated.

3. Although exploration at the individual deposits of Transbaikalia and Central Asia commenced as early as 1923-1925, their extensive and systematic study got under way only at the beginning of the First Five-Year-Plan. The basic investigations were carried out by the Institute of Economic Mineralogy (exploration, mineralogical study, concentration, and technology for the deposits of Transbaikalia, and Takob, and partly

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for those of Khaydarkan and Aurakhmat as well), GINTSVETMET (concentration), the Vaychag Expedition and GLAVSEVMORPUT' (exploration at Amderma), and the SOYUZhIMRUD Trust (exploration of the Aurakhmat deposit.)

4. In spite of the rapid growth of extraction, up to the... past year the fluorspar industry was unable to satisfy fully the demand of consumers, especially of iron and steel metallurgy. Even in 1934 fluorspar was still in short supply for the latter industry.

5. The absence of mechanical concentration, resulting in high losses of CaF_2 in the wastes, is a factor which renders the output of the finished chemical grade exceedingly difficult. Hand picking, which up to now has been the only method of concentrating the fluorspar here, yields a low-grade product that does not, on the whole, meet the requirements of the chemical industry. When the first concentration mill at the site of the Aurakhmat deposit is put into operation at the end of 1936, this backward condition should be liquidated.

6. At the present time there are three different organizations working fluorspar deposits: SOYUZPLAVIK, Aurakhmat Mining Administration, and GLAVSEVMORPUT'. In 1935 they extracted over 47,000 tons of fluorspar -- seven times as much as in 1928 and 1929.

7. As a result of the research work that has recently been done, the raw material base of the fluorspar industry of the USSR may now be considered studied in both geological and technological aspects, thus assuring the further successful de-

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velopment of that industry.

The necessity still remains, however, for continuing the search for new deposits in regions close to the centers of consumption (Urals, Western Siberia), and for further study of such major deposits as those of Amderma, Takob, Solonechnoye, Khaidarkan, Badam, and others, which will indubitably lead to the further expansion of the fluorspar base.

8. The fundamental lines of development of the fluorspar industry during the next few years will be determined in the main by the following four factors:

(a) The decree of the STO dated 27 August 1935 on the expansion of the wood-treating industry, providing for an expanded program of fluorspar production and of capital construction in the fluorspar industry during the period 1936-1938;

(b) The reduction of the norms of cryolite consumption by the aluminum industry and its partial replacement by aluminum fluoride;

(c) The partial change-over of the iron and steel metallurgical industry to the use of bauxite as a substitute for fluorspar in the production of basic open hearth steel;

(d) The possibility, thanks to the newly discovered major deposits at Amderma and Takob, of specializing the operations of the fluorspar producers for the output of definite grades based on the rational exploitation of the natural characteristics of the ores from the individual deposits.

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RESTRICTED**THE FLUORSPAR INDUSTRY IN THE CAPITALIST COUNTRIES**

Yu. L. Chernosvitov.

The small-scale handicraft working of fluorspar commenced very early in Europe. According to K. Engelbrecht, a small amount of it was mined in the Harz region of Germany as early as the 16th century. G. Tschermak mentions its use in the glass-making industry during the 17th century. But the systematic industrial exploitation of fluorspar deposits did not begin before the first quarter of the 19th century, while its widespread utilization came in only during the 20th century.

The United States is both the largest producer and the largest consumer of fluorspar, and its extraction constitutes half of the world production. The following figures for the past 11 years show the production of fluorspar in the United States, or rather, the amounts actually received by consumers, in thousands of tons: [The figures of actual production do not precisely agree with the figures for shipments, since the former also include the carry-over stocks remaining in the warehouses of the producers. This spread occasionally attains sizable proportion. Thus, for instance, 22,900 tons were shipped to consumers in 1932, while only ^{12,} 800 tons were produced during that year, and in 1933 66,300 tons were shipped and 53,630 tons produced.]

[See Table on Next page]

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1913	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935
104.85	103.11	115.80	102.00	127.45	132.30	86.95	48.52	22.90	66.00	79.00	111.56

According to the Bureau of the Census, the capital investment in the fluorspar industry of the United States reached 10 million dollars in 1929. The proportions of the various grades turned out by the American firms were as follows (average figures for 1920-1925): lump grade, 7.2 percent; gravel grade, 84.7 percent; ground grade, 8.1 percent.

The largest amount of fluorspar is mined from deposits in the states of Illinois and Kentucky. The total production of the Illinois mines from 1880 to 1934 is estimated at 2 million tons, that of the Kentucky mines for the same period, 1 million tons. These two states produce about 90 percent of the total for the United States. The ore reserves are estimated at approximately 3 million tons of crude ore for Illinois and 2.2 million tons of crude ore for Kentucky. At an average CaF_2 contentⁿ of 46 percent for Illinois ore and 52 percent for Kentucky ore, this gives a total of some 2.3 million tons of fluorspar. It must be observed, however, that these figures on ore reserves do not appear to be very trustworthy. In 1928 the Federal Tariff Commission investigated the situation of the fluorspar industry of the United States and stated in its report to the President that according to other information the reserves of commercial fluorspar in these states amounted to 4.6 million tons. Production and reserves in other

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states are so low as to be incomparable. Thus Colorado, third in production, yielded a total of about 165,000 tons for the entire 1880-1934 period. The yield of New Mexico was about 155,000 tons. Nevada had a total reckoned in tens of thousands of tons. During ~~the~~^{its} entire existence the fluorspar industry of the United States produced over 3.4 million tons of commercial fluorspar, thus consuming about half of the known reserves.

The largest mines are found in Illinois, in the neighborhood of the Rosiclare deposit. The Daisy mine, with an annual production of 40,000 tons of crude ore in 1929, stands in first place, but the Hillside and Spar Mountain mines have approximately the same productivity.

Large mines are an exception in the American Fluorspar industry. Most of the fluorspar is produced by small enterprises. During the war about 150 mines were producing it. The curtailment of fluorspar imports, which before the war had reached a fairly large tonnage, forced the American fluorspar industry to develop its own production to a maximum extent by working ^{on} economic high-cost deposits which could not be exploited under peace-time conditions. In essence this was the principal reason for the increase in the number of mines. With the resumption of fluorspar imports from Europe, the unprofitable marginal producers closed down, and the number of mines was cut in half. The relative proportions of the individual mines in production, however, remained roughly the same, since the total output was also halved. Davis estimates the number of mines operating in Kentucky alone to have been 35 during 1930, with average total annual productivity of 4000 - 5000 tons. In 1932, 40 mines were being worked in the whole of the

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United States, and the total domestic production, in terms of commercial fluorspar, amounted to 12,800 tons. In 1934, 91 mines were operating, with total extraction, in terms of commercial fluorspar, of 79,000 tons. During the last few years a fairly energetic concentration of fluorspar mines in the hands of large firms has been observed.

The construction of concentration mills at the separate small mines would have been obviously impractical, especially in cases where they were located close together, for such mills require fairly heavy capital investment. For this reason concentration mills in the United States generally serve not a single mine, but a number of neighboring mines, including not only those belonging to the mill-owner but also to other owners who do not do their own concentration but sell their ores in crude, unconcentrated state. Thus, for example, the Jamestown mill in Colorado handles ore from 6 mines. In Kentucky, the Franklin Fluorspar Company processes the ore of its own Hamp mine and also that received from a large number of other mines not owned by it.

The largest concentration mill in the United States belongs to the Rosiclare Lead and Fluorspar Mining Company and is located at Rosiclare in the state of Illinois.

It is of interest to note that at most mills fluorspar is concentrated by jigwork. There are very few flotation plants. Mineral Industry notes the commencement of operations at the Franklin Fluorspar Company's flotation mill in Illinois as one of the outstanding events of 1929.

As we have already mentioned, fluorspar production in the

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United States was drastically ^cut by the crisis. More than two-thirds of all the mines in that country were shut down in 193²₁, while the others operated on shortened work-weeks (in some cases, two days a week).

Before the crisis, during the 1926-1929 period, the average annual number of working days was 260. This fell to 135 in 1931, and was 147 in 1932. The number of workmen employed in the mines was also sharply reduced; in 1929, the estimated number for all mines was 1181, by 1931 it was only 732, and in 1932 it was 314. In 1932 the total number of shifts worked [i.e. man-days] at all fluorspar enterprises in the United States amounted to 46,160 as against 300,152 in 1929. The average length of the working day in the fluorspar mines was 8.14 hours in 1929, 8.34 hours in 1931, and 8.11 hours in 1932.

According to the Bureau of the Census, the average daily productivity of a fluorspar miner, in terms of commercial products, was 364 kilograms in 1926, 450 kilograms in 1931 and 277 kilograms in 1932.

These figures of average productivity fail to give a clear idea of the actual norms of productivity. Thus, during the period 1926-1933, the productivity per man-hour fluctuated between 32 and 50 kilograms in the Kentucky mines and between 36 and 76 kilograms in Illinois.

The average productivity per man-hour at the concentration mills was 51 kilograms of commercial fluorspar in 1929, 54 kilo-

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grams in 1931, and 34 kilograms in 1932.

The average mining cost per short ton of ore was six dollars and forty nine cents in 1925; the cost of preliminary cleaning and hand picking was three dollars and seventy cents, and that of mechanical concentration was three dollars and fifty two cents.

Comparison of the 1935 figures with those for 1934 shows some slight pick-up in all operations. Warehouse inventories of consumers still comprise exceptionally large stocks of fluorspar, however, and this is especially true of producers' inventories. The situation eased very insignificantly in the latter case, and 50 percent could be shipped out during 1935. Prices in 1935 declined somewhat from 1934 levels. Thirteen dollars and seventy six cents per short ton, f.o.b. mine, was the average paid for the metallurgical grade in 1935, while the imported product cost eighteen dollars and fifty cents to twenty dollars per short ton, including customs duty, and ground fluorspar cost twenty three dollars and fifty cents to twenty four dollars and fifty cents per short ton, f.o.b. mine. At the end of 1935 the metallurgical grade was selling for seventeen dollars and fifty cents a ton.

Although the United States is the largest producer of fluorspar in the world, it still imports it from other countries. This import was not interrupted even during the most acute stage of the crisis. It amounts to the average of about half the domestic production. Only during the final years of the depression did the percentage drop to around 20 percent.

The extensive use of imported fluorspar before the crisis

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is explained by the fact that its prices were lower than that of the domestic product. At the present time mostly high-grade material is being imported. Countries like Britain, France and Germany are competing fiercely on the American market. At first Britain took the dominant position, but was then displaced by Germany, which in turn was soon squeezed out by France, until France as well once more yielded to the supremacy of Germany.

[See next page for Table 1]

The report of the Tariff Commission mentioned above gives data on the comparative cost per short ton of metallurgical grade fluorspar domestically produced and imported from Great Britain.

At an average price of twenty dollars and sixty four cents per ton of American Fluorspar, f.o.b. mine, it costs twenty eight dollars and four(teen cents delivered at Philadelphia and twenty five dollars and eighty nine cents at Pittsburgh, (including freight.)

At the average price of seven dollars and fifteen cents a ton for British ore, f.o.b. a British port, it costs twelve dollars laid down in Philadelphia and fifteen dollars and seventy six cents in Pittsburgh.

It will thus be seen that, until the crisis, not only the price of British fluorspar but also its shipment to Philadelphia (which is, like Pittsburgh, a main center of the fluorspar trade) was cheaper than the price and shipping charges there for fluorspar produced in United States mines.

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TABLE 1

Basic Indices (in short tons) Showing the Position
of the Fluorspar Industry of the United States in
1934 and 1935

	1934	1935
Extraction of Crude Ore (in Terms of Commercial Fluorspar)	87,000	No Data
Shipments of Domestic Fluorspar		
Gravel Grade	74,249	105,280
Lump Grade	3,101	5,268
Ground Grade	8,436	13,013
	85,786	123,561
Stock Warehoused by producers or Held at Shipping Points		
Commercial Grades	50,586	33,389
Crude Ore	33,326	27,383
	83,912	60,752
Imports		
Fluorspar containing over 97 % CaF_2	10,632	10,578
Fluorspar containing under 97% CaF_2	6,073	5,762
	16,702	16,340
Exports	522	313
Consumption		
Iron and Steel Metallurgical Industries	88,100	108,400
Ceramics	11,500	16,700

(Continued on next page)

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(Table 1 cont'd)

Chemical Industry	11,000	12,900
	110,600	138,000
Stocks Warehoused by Consumers		
Iron and Steel Metallurgical Industries	47,400	49,600
Ceramics	2,500	2,800
Chemical Industry	7,700	5,600
	57,600	58,000

The same report of the Tariff Commission gives the following pre-crisis prices in dollars, for various grades of fluorspar per short ton, f.o.b. a foreign port. (Table 2).

TABLE 2

Countries	Grade		
	Metallurgical	Acid	Ceramic
Great Britain	8.87	13.49	-
Germany	8.53	20.73	22.21
France	7.63	14.93	12.68
Italy	8.69	-	17.57
Spain	6.48	14.25	-
China	10.45	-	13.88
Union of South Africa	-	18.15	-
Average price	\$8.53	\$18.27	\$20.80

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The Minerals Yearbook for 1935 gives the following 1933 and 1934 average prices for imported fluorspar, including duty, in dollars per ton:

Grade	1933	1934
Metallurgical	17.04	18.69
Glassmaking	25.75	28.79
Enamel	26.57	29.72
Acid	22.74	24.23
Cement	-	22.53

The following table gives the import figures for the past ten years, in thousands of tons:

1913	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935
23.7	67.6	63.9	42.6	48.5	58.5	18.7	11.9	9.45	14.54	14.73

Table 3 shows imports for 1933-1935.

Until the crisis imports consisted mainly of the metallurgical grade (81.6 percent in 1930), with the ceramic grade in second place and the acid grade in third place. At the present time the acid grade has the principal place in American imports, with 65 percent in 1935.

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TABLE 3

Imports of Fluorspar into the United States (in short tons)

Countries from which imported	Years		
	1933	1934	1935
Canada	-	187	1
China	27	112	-
France	204	-	-
Germany	4333	8224	9843
Italy	533	60	55
Newfoundland	320	724	-
Spain	4262	4914	5094
Great Britain	712	466	-
Union of South Africa	17	1997	1347
	10,408	16,705	16,340

It is extremely interesting to follow the fight that the American fluorspar industry has been carrying on for many years against imported fluorspar. Fluorspar was originally duty-free. An import duty amounting to three dollars a ton was imposed on it for the first time, by the United States, only in 1909, after the American fluorspar producers had persistently demanded it. Imports were naturally cut down in consequence, and the steel foundries, thus compelled to their disadvantage to buy expensive American Fluorspar instead of the cheap British product, were up

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in arms against this duty. Under their pressure, the duty was reduced to one dollar and fifty cents in 1913. In 1922, under a new drive of the American firms trading in domestic fluorspar, the government had to increase the duty to five dollars and sixty cents a short ton. But this step did not have the expected effect, and the duty was raised once more to seven dollars and fifty cents. The home producers repeatedly tried to force the government to raise it still more, but the owners of the steel foundries proved stronger, and the last law of 18 June 1930 kept the rate at seven dollars and fifty cents for fluorspar with up to 97 percent CaF_2 content, while the rate for spar with a higher content was fixed at five dollars and sixty cents.

The United States does not export its fluorspar. Its total exports are measured in hundreds of tons and are of a purely incidental character.

By far the largest amount of fluorspar is used by the United States in ferrous metallurgy (about 83 to 85 percent), with the glassmaking industry, using 7 to 9 percent, coming next, and the chemical industry, which takes about 3 to 4 percent, standing in third place. All other industries, including cement, use only 1 to 2 percent.

The number of enterprises that use fluorspar is very large. The Mineral Journal gives the following figures for 1926: ferrous metallurgy, 190 firms, including 54 making steel by the electric furnace method, 60 making pig iron, 4 making ferro-alloys, and 72

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making basic open hearth steel; chemical industry, 5 firms; enamel industry, 69 firms; glassmaking industry, 42; others 14; 320 firms in all.

During recent years the major American consumers have been attempting to acquire their own fluorite workings or at any rate to control them. Thus the United States Steel Corporation organized a special enterprise called the Lafayette Mining Co., through which it acquired large areas of fluorspar deposits in Mexico and Kentucky. The steel trust Briar Hill Steel Co. controls the fluorspar workings of the Ohio-Kentucky Fluorspar Co., the Aluminum Ore Co. has two of its own mines in Kentucky, etc. The trade in high-quality acid-grade fluorspar is, as a practical matter, entirely in the hands of the General Chemical Co.

Great Britain. The mining of fluorspar in Great Britain commenced somewhat later than in America, and was at first only incidental to the working of lead ores. The yield was insignificant, amounting to only 1000 to 2000 tons a year up to 1900. The American and Canadian demand for fluxes exerted a great influence on the development of the British fluorspar industry at the beginning of the 20th century. By 1913 the output of fluorspar in Great Britain had already reached very formidable proportions (54090 tons) reaching a figure of 65,000 in 1917, during the imperialist war.

After the war the output fell off by 20 or 30 percent, and during the crisis slumped in 1932 to 15,000 tons. The principal regions where fluorspar is worked are Derbyshire and Durham, while

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there are also small mines in Yorkshire, Cumberland, Cornwall, etc. Up to the war, fluorspar was recovered in Derbyshire by reprocessing the tailings and dumpings of old lead mines. But the exhaustion of these stocks has made it necessary, in recent years, to shift over to the exploitation of original beds. British fluorspar is low grade on the whole, and only a small proportion of the producers turn out the acid grade-- for instance, near Bonsall-Smith's mine, near Motloch, at Ashover, etc. The fluorspar mined in Derbyshire, which passed by the name of "Blue John", is famed for its rare beauty and is used in the jewelry industry. St. John's Chapel; Roorhope and Stanhope are the centers of fluorspar mining in Durham. In this area fluorspar is also extracted from old lead mines, but in this case not from the waste rock but by excavating into the rock walls that remain, which happen to be fluorspar ore. In Cumberland the Rotherhone mine should be mentioned. This mine belongs to the firm Ville Montagne-Zinc; after removing the galenite from its ore by jigwork, it yields an excellent gravel grade fluorspar.

The distribution of ^ffluorspar consumption among the various branches of industry is roughly the same in Great Britain as in America; the primary iron and steel industry uses about 80 percent, the chemical industry 10 percent, and all others, 10 percent.

Great Britain exports a considerable proportion of its fluorspar; its principal customer in recent years has been the United States. Canada occupies the second place, then British India and Australia. The recent curtailment of these exports has

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been directly due to the price-increases imposed by the necessity of working deeper and deeper seams, on the one hand, and to the reduction in demand by the United States for low-grade spar, on the other.

France did not mine fluorspar at all before 1880, though many of its deposits in the central massif were known as early as the first half of the 19th century. Here, too, the extraction of fluorspar was incidental to that of other minerals. Attention was focused on fluorspar only long after the working of the original mine had commenced. Thus, for example, the mine near Paulchaquet commenced to turn out fluorspar only in 1927, although it had been producing lead and barite since 1840.

M. Chermette and M. Sire state that during the period from 1880 to 1900, only two quarries were worked: LeBarlet and Voltenne. It was only after the major fluorspar deposits at Puy de Dome had been discovered around 1905-1906 that correct and systematic extraction commenced. But even during the war, when all countries with fluorspar deposits were vigorously stepping up their exploitation, the Puy de Dome workings still did not attain large proportions. In 1924, however, there was a boom in production, and a very sharp one at that, when 23,000 tons were suddenly thrown on the market. The boom lasted until the crisis had commenced, and production hit the record figure of 58,660 tons in 1930, shortly before that. The expansion of the French fluorspar industry is closely related to the increased exports to the United States, which in 1930 reached 10 times their 1925 level. In the beginning there were only mines in the region of the central

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massif. Then the workings in the Department of the Var were opened, which yielded about half the total output of 1928. Of the mines in the central massif, the Crot Blanc, with its excellently equipped concentration mill of 9000 tons capacity, should be pointed out, as well as the Voltenne, which once was the largest and most famous fluorspar mine. At Beaujolais, in the Puy de Dome Department, the Saint Etienne des Oullieres mine may be noted. Near Lastie, in the same Department, is the Beix mine, with a productive capacity of 7,000 tons, which is renowned for the exceptional purity of its product. The firm Alais Froges et Camargue owns a large number of small mines in the Haute Loire. In the Department of the Var the largest enterprise is the Esterel Mine, which belongs to the firm Carrieres et Mines d'Esterel, and has an annual productivity of 25,000 to 30,000 tons of crude ore.

The following are the figures in tons for production before the crisis, by the individual departments (the figures refer to 1929).

Var	26,000
Puy de Dome	5,300
Nievre	350
Haute Loire	1,000
Rhone	2,500
Saone et Loire	7,000
Indre	850
Aveyrone Losere	3,500

In the July 1935 number of the Journal Mines, Carrieres

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Chermette draws a cheerless picture of the situation of the French fluorspar industry during the crisis. Of the 25 enterprises that were operating in 1930, only 5 were working in 1934. Of these, two belonged to the firm of Alais, Frages Camargue, one to the Societe Teisset-Kessler and two to individual owners. Such great mines as Esterel and Voltenne closed down. The extracting of fluorspar fell in 1932 to 6000 tons, and recovered in 1934 to barely 10,000 to 12,000 tons. Its price fell catastrophically. In 1933 the metallurgical grade was selling for 98 francs, and in 1934 for only 70 francs, compared with 146 francs in 1928. France lost its principal customer, the United States. In 1935 it did not export a single ton to that country. Taking advantage of the preferential railroad freight rates which had been introduced in Germany, the Germans imported 2,162 tons of fluorspar in 1932, i.e. roughly 25 percent of the entire annual consumption of France, while in 1930 they had only imported 130 tons. In an effort to save the fluorspar industry the French capitalists established a special association called Comptoir Francais de Spath Fluor, which today controls 75 percent of French production.

French fluorspar is renowned for its purity, and is mainly used in the chemical industry. The firm Etablissements Teisset-Kessler, of Le Beix and Saint Germain, in the Department of Puy de Dome, sells two thirds of its production to chemical enterprises.

Germany is the fourth country where fluorspar is extensively mined. Before 1880 it held first place among fluorspar producers, outstripping even the United States. By the end of the 19th century,

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its annual production had already attained 6,000 tons. Meisner states that in 1900 the German production of fluorspar suddenly jumped to 28,000 tons and reached 40,000 tons in 1910. When export was cut off, thus freeing larger quantities for domestic consumption, the production of the operating enterprises easily met the increased demand of wartime. After the war the production of fluorspar fell sharply, mainly on account of the curtailment in the domestic demand from the primary iron and steel industry, which had shifted over to a substantial extent to smelting the scrap which remained in large quantities after the liquidation of the military stocks of war materials. In 1924 came the turning point. From then on the intensive growth of German Fluorspar production commenced.

According to Davis, it reached 107,000 tons in 1929.

The separate German provinces had the following shares in total [There can be no doubt at all that this means total annual production in Germany.] German fluorspar production during the period from 1919 to 1930, according to Medenbach:

	Amount in tons	Percent of total Production
Bavaria	27,000	30.0
Prussia	21,500	23.5
Saxony	11,350	13.5
Others	30,000	33.0
	90,000	100.0

The increase in production during the years immediately

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preceding the crisis may be explained to a large extent by Germany's successful struggle to dominate the American market.

As it did everywhere, the crisis compelled the German fluorspar industry to make drastic slashes in its production. In 1931 the output fell to 46,000 tons, and in 1932 to around 31,000 tons. There are no later figures, but the fact that in 1934 the total German fluorspar export amounting in all to 31,700 tons (including only 7,500 tons to the United States) admits of the assumption that there has still been no substantial recovery of the German fluorspar production, in as much as its fluorspar industry always exports at least half its production. Besides selling to America, Germany also sells its fluorspar to Poland, Czechoslovakia, Austria, Sweden and Belgium. The total of German fluorspar exports to these countries even exceeds that to the United States. During recent years it has likewise commenced to export to France. The largest fluorspar mine in Germany is ^S/_X the Flussschacht at Rottleberode in the southern Harz, which belongs to the Rheinische Fluss- und Schwerspatwerke ^G/_X m.b.H.

The following enterprises produce relatively large quantities of fluorspar: Prinz Carl, in Thuringen, owned by Gewerkschaft Prinz Carl, at Sonderhausen; the Sulzbach mine, in Oberpfalz, near Donaustauf, owned by Rheinische Fluss- und Schwerspatwerke G.m.b.H.; the ^{Oe}/_X Sulzbach mine near Oberkirch, in the Schwarzwald; the Klinge mine near Wernhausen in Thuringen; the Edelweiss and Silberbach mine in the Harz, near Stolberg, owned by Spatwerke and Erdfarbenindustrie A. G., Dresden, and a considerable number of others.

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According to Medenbach, 26 firms were operating in Germany until the crisis, of which the largest, Bergbau A. G. Lothringen, Abteilung Mathildenhutte, Hannover, marketed more than 30,000 tons a year.

The average production cost of commercial fluorspar in Germany before the crisis did not exceed 30 marks a ton. The selling price for high-grade material during 1931 and 1932 fluctuated between 65 and 67 marks a ton; metallurgical fluorspar sold at 15 to 20 marks, and the particularly high-grade ground product, with 98 percent to 99 percent CaF_2 content, brought from 70 to 100 marks. The "Union of Owners of Fluorspar Enterprises" has been functioning in Germany for many years, with insignificant interruptions, to regulate trade and prices. It allocates the orders among its members and fixes selling prices which are binding on them. 16 (out of 26) of the largest producers of fluorspar belong to this Union. A preferential freight tariff for shipments of fluorspar from the place of production to the place of consumption was established in Germany in 1932. With increasing distance the tariff rate [i.e. per ton-kilometer.] is progressively reduced. The tariff applies to both the state railroads and the privately owned lines.

All the other capitalist countries that produce fluorspar in relatively small amounts, play no appreciable part whatsoever in the world turnover.

China may be mentioned. It produces 8,000 to 9,000 a year. Spain has considerably stepped up its export to the United States

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during the last few years, and now takes second place after Germany in that export market. There is some indication that the level of production in Spain, before the crisis, had reached 14,000 tons. During the crisis it fell to 3,500 to 5,000 tons. Italy, according to Ladoo, produced 1,600 tons of fluorspar in 1918, but increased this figure to 6,000-7,000 tons in the following years. In contrast to other countries, the fluorspar industry in Italy has only been slightly affected by the crisis. The largest of the Italian mines is the one in the Venetian Alps, the daily production of which can be brought up to 50 tons. It has a concentration mill, and turns out a high-grade product with a CaF_2 content of 92 percent. In 1926 a certain slight animation of the production in Northern Australia (Chillagoe^o district) was noted. A short time before the crisis, according to the Eng. Min. J., a major deposit was discovered in Norway. There, however, the production is still not over 600 to 800 tons a year. In 1935 12,000 tons was mined in Korea.

After the war Canada produced a fairly large amount, yielding 16,211 tons in 1929 (the Rock Candy mine in British Columbia) but since 1930 production in Canada has almost entirely ceased. In 1930 the total production was 74 tons, in 1931, 36 tons, in 1932, 29 tons, in 1933, 66 tons, and in 1934, 136 tons. Canadian consumers have completely gone over to the use of imported fluorspar. In 1933 a small working was started in Newfoundland. The mines in the Burin East and Burin West Districts yielded about 1450 tons of metallurgical fluorspar in that year, and increased the production to 2,540 tons in 1934. The Union of South Africa puts not

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more than 20,000 tons on the world market, and exports almost its entire production to the United States. Before the crisis insignificant production was also noted in Southeast Africa. Tables, 4, 5, and 6 show the summary figures of world production in 1913 and for the period 1929-1934, as well as data for export and import for the same period.

TABLE 4
World Production of Fluorspar in 1913 and during
the period 1929-1934. (in thousands of tons)

Countries	Years						
	1913	1930	1931	1932	1933	1934	1935
Great Britain	54.52	30.26	20.24	15.67	28.40	34.76	-1
Australia	-	0.97	0.54	1.28	1.00	1.76	-1
Argentina	-	-	-	0.01	0.20	0.31	-1
Germany	3.26	82.71	46.47	32.36	10.60 ²	70.04	-1
Canada	-	0.07	0.03	0.02	0.06	0.13	0.24
China	-	2.29	2.64	7.57	9.07	7.1	-1
Korea	-	-1	-1	-1	-1	12.9	-1
Italy	-1	6.65	5.85	6.45	7.71	4.94	9.50
Spain	3.51	11.29	6.61	7.01	3.56	6.36	-1
Mexico	-1	-1	-1	-1	-1	0.9	-1
United States	104.85	86.95	48.52	22.99	66.16	77.80	112.09 ³
France	7.52	58.66	23.80	-1	-1	-1	-1
Union of South Africa	-	1.50	2.19	1.31	0.44	1.39	1.73
South East Africa	-	-	-	0.61	-1	1.39	-1
Japan	-	2.29	-1	-1	-1	-1	-1
1 - No Data	2 - Data incomplete	3 - Figure shows shipments.					

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TABLE 5

Import of fluorspar by countries, in 1913, in 1925
and for the period 1929-1934 (in thousands of tons)

Countries	Years							
	1913	1920	1929	1930	1931	1932	1933	1934
Austria	10.9	1.0	5.1	4.3	-1	-1	-1	-1
Belgium	4.2	3.6	1.1					
Hungary	-	0.5	-1	-1	-1	-1	-1	-1
Germany	0.2	2.0	0.2	0.1	-1	-1	-1	-1
Denmark	-	0.7	0.8	0.8	-1	-1	-1	-1
Canada	-	-	10.8	11.4	-1	-1	2.2	7.2
Norway	-	0.2	2.3	2.8	-1	-1	-1	-1
Newfoundland	-	-	-	-	-	-	2.9 ²	6.9 ²
Poland	-	2.8	5.7	-1	-1	-1	-1	-1
United States	23.7	43.0	48.5	58.5	18.8	12.0	9.4	15.2
Czechoslovakia	-	9.2	10.1	-1	-1	-1	-1	-1
Switzerland	-	0.4	-1	-1	-1	-1	-1	-1
Yugoslavia	-	0.4	0.9	0.8	-1	-1	-1	-1

1- No data

2- Imported into the United States

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It still remains for us to say a few words about transparent optical fluorspar. Its production is usually carried on incidentally, during the mining of ordinary fluorspar, by way of selecting the purest, colorless crystals. The crude optical material so selected, however, gives very many rejects (about 95 percent), and brings a relatively low price on the world market--from 2 to 25 dollars a kilogram. According to Herbert Hughes, in order to improve the above selection and at the same time furnish the producers an incentive, a number of optical factories have recently adopted a method of computing payment calculated to improve the method of selection and simultaneously giving the producers an incentive to cooperate. They pay the supplier not by the weight of the yield of the raw material delivered, but by the weight of the yield of the finished product. This measure not only led to more careful selection, but suddenly raised the price for crude optical fluorspar to 115- 200 dollars a kilogram.

[See table 6 on next page]

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TABLE 6

Export of fluorspar, by countries, in 1913, in
1925, and for the period 1929-1934
of
(in thousands tons)

Countries	Years						
	1913	1925	1929	1930	1931	1932	1933 1934
Great Britain	5.3	25.2	15.0	23.30	-1	-1	-1 -1
British Africa	-	-	1.1	-1	-1	-1	-1 -1
Germany	25.5	32.1	51.4	44.7	26.7	20.3	24.9 31.7
Spain	-	-	5.4 ²	6.0 ²	3.6 ²	2.1 ²	3.9 ² 4.5 ²
Italy	-	3.8	1.0	1.7 ²	1.4 ²	1.3 ²	0.4 ² 0.06 ²
China	-	0.6	1.2	-1	-1	-1	0.02 ² 0.1 ²
United States	-	1.0	0.5	0.2	0.3	0.02	0.07 0.5
France	-	4.3	15.0	21.1	4.1 ²	1.4 ²	1.9 ² -2
Union of South Africa	-	6.4	4.1	1.9	2.8	1.3	0.8 1.8

1 - No data

2 - Exported to the United States

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